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PREVALENCE AND TIMING OF ENAMEL HYPOPLASIAS IN THE VAGNARI SKELETAL SAMPLE (1^{ST} – 4^{TH} CENTURIES A.D.)

by

Chrystal Lea Nause

B.A., Southern Illinois University Carbondale, Magna Cum Laude, 2005

A Thesis
Submitted in Partial Fulfillment of the Requirements for the
Master of Arts Degree

Department of Anthropology
in the Graduate School
Southern Illinois University Carbondale
August 2010

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THESIS APPROVAL

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Chrystal Lea Nause

A Thesis Submitted in Partial

Fulfillment of the Requirements

for the Degree of

Master of Arts

in the field of Anthropology

Approved by:

Dr. Tracy L. Prowse, Chair

Dr. Robert S. Corruccini

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Graduate School
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May 10, 2010

AN ABSTRACT OF THE THESIS OF

CHRYSTAL LEA NAUSE, for the Master of Arts degree in ANTHROPOLOGY, presented on May 10th, 2010, at Southern Illinois University Carbondale.

TITLE: PREVALENCE AND TIMING OF ENAMEL HYPOPLASIAS IN THE VAGNARI SKELETAL SAMPLE (1ST – 4TH CENTURIES A.D.)

MAJOR PROFESSOR: Dr. Tracy L. Prowse

This thesis investigates infant and childhood health in the Roman period (1st to 4th centuries A.D.) cemetery at Vagnari using data on the prevalence and timing of linear enamel hypoplasias (LEH's). These results are examined in the context of historical and archaeological evidence for childhood health in ancient Rome. Analysis of the prevalence of LEH's in 48 individuals reveals a low frequency (64.6 %) of enamel hypoplasias in comparison with other Roman period skeletal samples, suggesting that political-economic or geographical variables may have contributed to the generally healthy conditions for subadults at Vagnari.

Intrasite analysis indicates no significant difference between sexes or burial types with respect to the average number of teeth affected with hypoplasias and the average total number of defects, but a significant difference does exist between age groups (divided into 15 year intervals). The hypoplastic data indicate that males and females were experiencing similar levels of stress during infancy and childhood. These results are not consistent with the historical evidence, which suggests that male children were preferentially treated in ancient Roman society.

Measurement of each hypoplastic defect indicates a peak age at occurrence of 2.75 years of age, which is interpreted as evidence of the end of

the weaning process. Enamel hypoplasias occurred until around 6.5 years of age, suggesting that these Roman children experienced stress throughout childhood, possibly the result of childhood illness or malnutrition. The hypoplastic data are consistent with the historical evidence from the Roman period with respect to the general timetable of weaning. This research integrates biological, archaeological, and historical information about the lives of children to help investigate the physical well-being of a rural working class population in the ancient Roman Empire.

DEDICATION

This thesis is in honor of Jim, Alma, Evelyn, and Al. I wish you could be here to celebrate this accomplishment.

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CHAPTER 1

INTRODUCTION

Enamel hypoplasias (EH's) are areas of reduced enamel thickness on a tooth crown that result from a temporary disruption in the normal process of tooth enamel formation (Goodman et al., 1984a; Goodman and Rose, 1991). These enamel defects most commonly occur as horizontal grooves (linear enamel hypoplasia or LEH), but pitting on the tooth enamel is also commonly observed (Hillson, 1996; Goodman and Song, 1999). They are categorized as non-specific indicators of systemic stress (Goodman and Rose, 1990). A non-specific indicator of stress is a response that is visible on the dentition or on the skeleton but is not associated with a specific cause.

The precise etiology of EH's is not well understood and, although biological and cultural stress coping mechanisms exist at the individual level, researchers have demonstrated that malnutrition, nutritional deficiencies, disease, and low social economic status are factors that likely contribute to EH formation (e.g., Chavez and Martinez, 1982; Flinn and England, 1997; Goodman and Armelagos, 1989; Goodman et al., 1980; Haas and Pelletier, 1989; Lovell and Whyte, 1999; Schell, 1997; Shell-Duncan, 1997; Zhou, 1995; Zhou and Corruccini, 1998, among others). Recent research has also demonstrated that different types of EH defects (i.e., linear and pit) may have separate etiologies (e.g, Griffin and Donolon, 2009).

Hypoplastic defects can affect all tooth crowns, though some research has demonstrated that there can be differences in susceptibility related to age, sex, and tooth type (e.g., Goodman and Armelagos, 1985; Goodman et al., 1987; Hillier and Craig, 1992; Marks and Rose, 1985; Massler et al., 1941; Šlaus, 2000, 2008). Because enamel deposition occurs at predictable rates, the approximate timing of the hypoplastic incident can be calculated. The location of these temporary amelogenesis disruptions can be measured and then converted with a dental eruption chart into an approximate age at occurrence (Goodman et al., 1980; Massler et al., 1941; Swärdstedt, 1966). Enamel Hypoplasias are useful because they record the survival of a nonspecific stress episode. In these ways, enamel defects are utilized to infer overall health and quality of life during the time that teeth were forming (i.e., during infancy and childhood) (Goodman et al., 1980).

It is important for researchers to understand what everyday life was like for the majority, rather than only a minority, of any population. One of the limitations in the historical record from the Roman period is that the majority of the texts focused on the life ways of elite members of society. These types of historical documents were commonly commissioned by privileged organizations or individuals (i.e., political leaders, religious organizations, etc.) and had a bias towards describing the lives of their literate, elite audiences (Woods, 2005). In addition, much of our understanding of these segments of Roman society has been reconstructed by means of literary and artistic depictions, while the skeletal remains have been largely overlooked (Killgrove, 2005). This can be problematic due to an exclusion of common, everyday occurrences that describe what life was for many Roman people. Information about this non-elite segment of Roman society, who formed the vast majority of the population, merits further investigation.

Killgrove (2005:65) argued that investigators “need to examine people from all social perspectives, not just the ones the elite [writers] immortalized in texts” as a means of fully understanding Roman society. Furthermore, she suggested that the overall lack of skeletal data in Italian scholarship is related to the relatively non-existent role of bioarchaeology in traditional Roman period studies (Killgrove, 2005). Skeletal remains are a rich source of information on life and death in ancient Rome. One of the earliest population-level studies on skeletal remains in the Mediterranean was done by Angel (1966), who examined porotic hyperostosis in relation to anemia and malaria in this region. Since that time, only a limited number of studies (other than simple site reports) have involved the direct investigation of human skeletal remains to investigate health in the Roman period, including evidence of enamel defects (e.g., Belcastro et al., 2007; FitzGerald et al., 2006; Hoover, 2001; Hoover et al., 2005; Lovell and Whyte, 1999), dental disease (e.g., Bonfiglioli et al., 2003; Manzi et al., 1999), porotic hyperostosis (e.g., Ricci et al., 1997; Salvadei et al., 2001), cribra orbitalia and cribra cranii (e.g., Facchini et al., 2004), exposure to lead (e.g., Aufderheide et al., 1992), bone loss of the rib (e.g., Cho and Stout, 2003), stable isotope analysis (e.g., Prowse et al., 2004, 2008), stature (e.g., Giannechini and Moggi-Cecchi, 2008), and general health assessments (e.g., Cucina et al., 2006; Paine et al., 2007; Paine et al., 2009; Prowse, 2007; Prowse and Small, 2009). Few bioarchaeological skeletal studies have specifically focused on the everyday life and health of lower- and middle-class laborers of ancient Rome (e.g., Cucina et al., 2006; Manzi et al., 1999). Even less information is available concerning childhood nutrition and health of such working classes.

The goal of this thesis is to use EH prevalence to investigate childhood health among individuals recovered from the rural Roman cemetery at Vagnari (1^{st} – 4^{th} centuries A.D.). Vagnari is located12 km south of the modern city of Gravina in Puglia, Italy, and is the largest known Roman Imperial site in the area (Small et al., 2003). It is thought to be located near the *Via Appia*, a key trade route that connected the city of Rome to the southern part of Italy. The location of Vagnari along important communication and trade routes suggests that this site was an important economic center for the region (Small, 2005). Archaeological evidence from the site of Vagnari indicates that these people were physical laborers living on an Imperial Estate, suggesting that the individuals from Vagnari may demonstrate high frequencies of hypoplastic enamel defects indicative of high levels of childhood stress (Prowse, 2007).

Specifically, this investigation explores the prevalence and timing of hypoplastic events and individual susceptibility to EH's in relation to sex, age at death, age at incident, dental arcade, tooth type, and burial type in this Roman skeletal sample. Since political and cultural circumstances have the ability to mitigate or exacerbate stress levels, Vagnari is compared to other contemporaneous samples in order to demonstrate the overall level of stress experienced by these individuals within a broader context of health in Roman Italy. The results will be examined within the historical context of the Roman Imperial period, which provides evidence on potential stressors experienced by Roman infants and children living on a rural estate. By providing a historical framework for this research by means of a biocultural approach, important information on the physical well-being of a rural working class population in the ancient Roman Empire can be presented, and will contribute to a broader bioarchaeological reconstruction of the lives of a relatively unknown segment of the Roman population.

CHAPTER 2

LITERATURE REVIEW

The human skeleton is capable of responding to environmental stressors and can potentially reveal information about the overall level of health in a population and, more specifically, about the life history of an individual. Skeletal evidence for the occurrence of stress-related events (e.g., disease, malnutrition) can aid researchers in understanding the lives of past populations and the possible biological and social causes of these stress events. Teeth are also capable of exhibiting both external and internal defects in response to stress.

An enamel hypoplasia (EH) is an example of a non-specific stress response that is visible on the enamel of a tooth. Non-specific indicators of stress are generalized responses visible on the human skeleton and dentition that cannot be linked to specific causes, but can be used to infer overall heath and quality of life. These enamel defects can appear as pits, horizontal grooves (linear enamel hypoplasia or LEH), vertical grooves, or areas of missing enamel on the tooth crown. Most researchers agree that temporary developmental disruptions during amelogenesis (tooth crown formation) can result in EH's (Goodman et al., 1984a; Goodman and Rose, 1991). These defects persist as a permanent record of developmental disruption, since enamel does not remodel after deposition, and are therefore an ideal source of information about stresses experienced during infancy and childhood (since permanent tooth crowns develop during infancy and childhood). Tooth enamel is also resistant to postmortem degradation, so it preserves well in the archaeological record.

Tooth Development and the Formation of Enamel Hypoplasias

Tooth crowns first begin to form in utero and continue to develop until approximately 15 years ($\pm$ 3 years) of age (White and Folkens, 2005). Dental enamel is a hard protective layer that is laid over dentine in a forming tooth, and helps to protect dental pulp and nerves found in the central portion of the tooth. Organic enamel matrix deposition (see Figure 1) occurs in incremental layers beginning at the occlusal (or biting) surface of the crown and ceasing at the cemento-enamel junction (CEJ) (see Figures 2 and 3). This means that defects located closer to the occlusal surface occurred earlier in the development of the tooth crown, and those found closer to the CEJ occurred later.

The CEJ (see Figure 3) is the area where the enamel meets the cementum, only occurring at the point where the tooth crown and root join (Hillson, 2005). After enamel matrix deposition is finished, ameloblast cells replace the organic components with inorganic calcium phosphate, which continues to develop until maturation of the enamel is complete (Hillson, 1996). Normal tooth enamel formation can be interrupted by many variables (i.e., stressors) including birth (resulting in the microscopic “neonatal line”), weaning, nutritional deficiency, subsistence changes, illness, and low socioeconomic status (Bogin, 1999; Hoover, 2001). The terms “stress” or “stressors” are commonly used to refer to periods of adversity such as the aforementioned conditions.

Zsigmondy (1893) first employed the term “enamel hypoplasias” in his exploration of congenital enamel defects. An EH is most commonly defined as a localized deficiency of enamel thickness that is the result of systemic disruption of amelogenesis, the enamel matrix secretion phase of tooth crown development carried out by ameloblasts (Goodman et al., 1980; Sarnat and Schour, 1941). Disturbances of enamel matrix production can range from a short-term cessation of depositional activity to a permanent interruption in enamel deposition. Regardless of whether the ameloblast cell recovers, the result of any disturbance is thinned enamel that circumscribes the tooth crown in localized bands (Hillson, 1996).

A counterpart to the EH is the internal enamel defect known as “irregular” striae of Retzius or, more commonly, Wilson bands (WB’s), which might result from a mild stress (Massler et al., 1941; Skinner and Goodman, 1992) or short periods of metabolic disturbance (Condon, 1981; Wright, 1990). FitzGerald and Saunders (2005) found that all physiological stressors leave WB’s, regardless of severity or duration. Some research has demonstrated a correspondence between WB’s and EH’s (e.g., Simpson, 1997), although there is still much controversy on the subject (Karhu, 1991; Wright, 1990). Normal striae of Retzius, commonly referred to as brown striae, form with regular development and are similar to the perikymata that form on the enamel surface (Hillson, 2005).

A variety of classification techniques have been used to record EH's. In their seminal discussion of hypoplastic defects, Hillson and Bond (1997) identified three types of defective enamel structure: pit form, plane form, and furrow form (or LEH) (see Figure 4). The plane form defect is one which reveals the underlying normal or brown striae of Retzius. The Fédération Dentaire Internationale (1982, 1992) has distinguished six different types of enamel defects: enamel opacities colored white or cream, enamel opacities colored yellow or brown, pits (enamel pitting), horizontal grooves (LEH), vertical grooves, and missing enamel. Hypoplastic defects most commonly manifest as horizontal grooves and pits and, in some cases, the enamel can be so underdeveloped that the enamel-dentine junction (EDJ) is exposed.

The most recognizable type of enamel defect is the linear enamel hypoplasia (LEH), which can vary drastically in thickness from a microscopic line to a broader macroscopic furrow (see Figure 5). Linear enamel hypoplasias follow the horizontal direction of perikymata and are the result of variations in perikymata spacing and prominence (see Figure 1) (Hillson, 2005; Hillson and Bond, 1997; Hillson et al., 1999). Perikymata are the sloping ridges formed in regular intervals on the external surface of tooth enamel and can be seen microscopically in normally developed dentition (Hillson, 1996). Each LEH thus correlates with the chronological development of the tooth enamel.

Another type of EH is pitting that can vary in expression from a single pit to a band of pits. These pits can be found alone or in association with LEH's (see Figure 4) (Hillson, 2005). The anterior teeth are typically more susceptible to hypoplastic defects, so many EH studies have focused on the permanent maxillary central incisors and mandibular canines as recommended by Goodman and Rose (1990) (e.g., Belcastro et al., 2007; Corruccini and Townsend, 2003; Corruccini et al., 2005; Facchini et al., 2004).

One of the limitations in using only the permanent maxillary central incisors and the mandibular canines is that enamel formation of these teeth nears completion around the age of 7 years (± 2 years) (White and Folkens, 2005). This relatively early completion excludes information about older subadults, particularly when compared to the third molar, which does not complete crown formation until 15 years (± 3 years) of age (White and Folkens, 2005). Due to the limitations associated with excluding some teeth from analysis, other researchers have investigated the prevalence of LEH's on posterior teeth (e.g., Brothwell, 1963; Cook, 1984; Cucina et al., 2006; Dobney and Ervynck, 2000; FitzGerald and Saunders, 2005; King et al., 2002; Lovell and Whyte, 1999).

Etiology of Hypoplastic Defects

The etiology of EH's has been widely debated, but most researchers agree that temporary developmental disruptions during tooth crown formation can result in EH's (Goodman et al., 1984a; Goodman and Rose, 1991). Three main etiological factors are responsible for the formation of enamel defects; hereditary abnormalities (involving the whole crown), local trauma (appearing on a single tooth or on adjacent teeth), and metabolic stress (Pindborg, 1970; Winter and Brook, 1975). It is generally agreed that environmental stressors occur more frequently than hereditary anomalies (Goodman and Armelagos, 1985; Goodman and Rose, 1990, 1991; Hillson, 1996; Lukacs, 1992; May et al., 1993; Moggi-Cecchi et al., 1994; Seow, 1991; Skinner and Goodman, 1992).

Past research strongly linked hypoplastic defects to nutritional deficiencies and disease (e.g., Goodman and Armelagos, 1989; Zhou, 1995; Zhou and Corruccini, 1998). Clinical studies have linked enamel defects to a number of systemic and physiological stressors such as malnutrition and micronutrient deficiencies (e.g., Chavez and Martinez, 1982; Goodman et al., 1991; Infante and Gillespie, 1977; Shell-Duncan, 1997; Solomons and Keusch, 1981) and a variety of diseases such as rubella, tetanus and syphilis (e.g., Pindborg, 1982). Weaning is a particularly hazardous period when infants are susceptible to malnutrition and disease with the introduction of new food sources and the loss of passive immunity from breast milk (Rodney, 1983). This seems very probable due to the relationship between malnutrition and illness; poor nutrition can significantly decrease one's ability to cope with stressful conditions that predispose oneself to illness. Lovell and Whyte (1999:70) also noted that "…the interaction of two or more factors, particularly diet and disease, is now understood to be involved" in the etiology of EH's. Poor nutrition and illness is also significantly correlated to low social economic status, so all of these factors likely play a role in the etiology of EH's (Blakey and Armelagos, 1985; Cook and Buikstra, 1979; Enwonwu, 1973; Goodman et al., 1980).

Recent research by Griffin and Donlon (2009) suggested that linear and pit enamel hypoplasias may have different etiologies. While Griffin and Donlon (2009) agreed with previous research that the etiologies of LEH, linear, and non-linear arrays of pits are linked with nonspecific systemic stressors (i.e., nutritional deficiencies and systemic diseases), they suggested that single pits may arise from a different cause. Single pits, more commonly found in the deciduous dentition, seem to be caused by stress experienced perinatally or during infancy when the tooth germ is still unerupted in its crypt (Griffin and Donlon, 2009).

Susceptibility

Hypoplastic defects can be found on all tooth crowns, however, there can be differences in susceptibility based on age, sex, and tooth type. Massler and colleagues (1941) noted that EH's were more likely to occur during the first 10 months of life than during any other time of tooth enamel formation. Children were also found to be more susceptible to physiological stressors during the neonatal period, 10 months, 2.5 years, and 5 years of age when compared to other developmental time periods (Massler et al., 1941). Four periods of growth disturbance were found associated with each of the aforementioned time periods (birth, 10 months, 2.5 years, and 5 years) and, according to Massler and co-workers (1941), can be attributed to different causal mechanisms.

The microscopic "neonatal line" is found in enamel correlating with the neonatal period, or the period around the time of birth. According to Massler and colleagues (1941), this line reflects an arrest in growth after birth and the physiologic adjustments to environmental change. The infancy period, which occurs after the neonatal period and ends around the 10th month of life, is a time when metabolic and cellular activities are very susceptible to disturbances (i.e., disease, rapid growth, etc.) (Massler et al., 1941). Before the culmination of the infancy period, Massler and colleagues (1941) identified the formation of an "early infancy ring" around 6 months of age. The "early infancy ring" is generally less prominent and occurs less frequently than the other types of accentuated lines (Massler et al., 1941). Enamel formation quality declines until the 10th month, when systemic disturbances end abruptly and culminate in an "infancy ring", which generally manifests as pitting of the enamel (Massler et al., 1941). The early childhood and later childhood rings occur during periods when metabolic and cellular processes are relatively immune to systemic disturbances. Massler and co-workers (1941) attribute these rings, which are less accentuated than the neonatal and infancy rings, to susceptible periods in the metabolism of a growing child that may be linked to changes in growth rates.

Although hypoplastic defects have been linked to sex-related patterns of susceptibility, the results of studies have varied. In their study of permanent dentition in rural Mexican children, Goodman and co-workers (1987) found a higher frequency of females affected, which they attributed to differential access to resources based on sex. Šlaus (2000) suggested that females in a Late Medieval Croatian population were disproportionately much more susceptible to EH formation than males. Historic records indicated that females were often subjected to greater levels of stress than their male counterparts, such as differential access to resources, which could also contribute to sex-related patterns of EH vulnerability (Šlaus, 2000).

In contrast to this earlier study, Šlaus (2008) reported that Croatian males and subadults were more susceptible to physiological disturbances (i.e., cribra orbitalia and LEH) during the Early Medieval period. These differences in sex-related patterns of susceptibility were largely attributed to changing local cultural, socio-economic, and political conditions (Šlaus, 2008).

Other studies have reported no statistically significant differences in susceptibility between the sexes (e.g., Griffin and Donlon, 2009; Guatelli-Steinberg and Lukacs, 1999; Hoover et al., 2005; Lovell and Whyte, 1999). It seems that sex-based patterns of susceptibility differ widely and are more likely the result of socio-cultural differences rather than biological ones.

Marks and Rose (1985) proposed that certain tooth types are more susceptible to growth disruption during crown development than others. In their study of EH's and WB's in Libben site materials (Ottawa County, Ohio, 800 to 1100 A.D.), canine teeth exhibited a greater variability of hypoplastic defects when compared to premolars (Marks and Rose, 1985). This evidence suggests that differential tooth susceptibility, rather than differing causes, influences the overall appearance of the observed EH's. A contemporaneous study on prehistoric Amerindians similarly found anterior teeth more susceptible to insult when compared to posterior teeth (Goodman and Armelagos, 1985). In particular, maxillary first incisors were found to be more susceptible at early periods of tooth crown formation and mandibular canines at later periods of development (Goodman and Armelagos, 1985). In addition, the polar or earlier developing teeth in each tooth class (the maxillary central incisors, mandibular lateral incisors, and all canines, first premolars, and first molars), which are thought to be the most developmentally stable teeth also demonstrated a greater tendency towards hypoplastic defects (Goodman and Armelagos, 1985). Goodman and Armelagos (1985) suggested that polar teeth are more likely to form hypoplastic defects in response to physiological stress because genetics strongly control the size and shape of these teeth. Teeth that are under greater genetic control may be less able to alter their size and developmental timing in response to environmental stress, so EH formation may be the only physiological response available for these polar teeth (Goodman and Armelagos, 1985).

In addition to these earlier studies, Hillier and Craig (1992) suggested that teeth with longer periods of crown development (i.e., canines) could be more prone to EH defects simply due to their slower rates of enamel deposition. According to Ubelaker's (1978) dental development diagram, based on Schour and Massler's (1941) original development diagram, permanent crown development periods vary according to tooth type. Table 1 shows how many years (approximately) of development according to tooth type.

Timing of Hypoplastic Defects

Another area of interest to biological anthropologists is the timing of these dental disruptions since tooth formation occurs at predictable rates. If the timing of the defect can be determined, then not only can we say that an individual experienced one or more stress events during the formation of a particular tooth crown, we can indicate approximately when those stress events occurred. Approximate age during the stress occurrence has been estimated by measuring the position of macroscopic enamel defects on the crown surface (e.g., Buikstra and Ubelaker, 1994; Goodman and Rose, 1990; Moggi-Cecchi et al., 1994; Rose et al., 1985). Swärdstedt (1966) first introduced a method that involved measuring the distance between the CEJ and the most occlusal portion of the defect. The occlusal edge of the defect represents the onset of the physiological disturbance. The measurements were then converted into ages at occurrence using a dental eruption diagram from Massler et al. (1941). According to Buikstra and Ubelaker (1994), the distance from the occlusal tip of the crown to the defect provides a more accurate estimate of the age at the time of insult, but the method utilized by Swärdstedt (1966) is more practical because of possible attrition of the occlusal surface. Other studies such as those conducted by Goodman et al. (1984a) and Goodman and Rose (1990) have used a modified version of the Swärdstedt (1966) method (modified by Goodman and co-workers in 1980). Buikstra and Ubelaker (1994) have recommended the method outlined by Goodman and co-workers (1980) as a data collection standard.

Although there are many proponents utilizing this metric method to determine the timing of dental defects, some have suggested that the chronology can be incorrect by up to a year due to differences in growth between the sexes and between different demographic groups (Hillson, 1992b; Lovell and Whyte, 1999; Ritzman et al., 2008). King and co-workers (2002) suggested that there are a number of problems associated with utilizing the methods proposed by Massler et al. (1941) that were modified by Swärdstedt (1966) and Goodman et al. (1980). An inherent problem is that they assume a constant linear growth rate for tooth crowns when there are actually varying rates between individuals and populations (Goodman and Song, 1999; Hillson, 1992a, b; Hillson and Bond, 1997; Reid and Dean, 2000; Skinner and Goodman, 1992).

A recent study by Ritzman and colleagues (2008) tested three methods used to determine the timing of enamel defects: the chart method (after Buikstra and Ubelaker, 1994), regression equations (after Goodman and Rose, 1990) and histological data (after Reid and Dean, 2006). Goodman and Rose (1990, 1991) asserted that these chronology reconstructing methods could be refined by using regression equations. Their regressions were based on the mean crown heights from the dental development standards of Massler et al. (1941) and Swärdstedt (1966) where velocity is based on the rate of enamel calcification as established by Massler et al. (1941) using the following equation:

Age at LEH formation = - [(1/velocity) x distance of LEH from CEJ] + age at crown completion

Reid and Dean (2000) divided tooth crowns into equal tenths and then calculated the number of days it would take for each tenth to grow. By summing up these ten calculations, adding an estimate for the number of days required for cuspal enamel formation, and adding the number of days between birth and crown initiation, calculated ages at crown completion were obtained (Reid and Dean, 2000). The study conducted by Reid and Dean in 2006 was the application of this method to large samples from different locations (i.e., northern European and southern African).

The tests revealed that the histological method utilized by Reid and Dean (2006) produced ages older than both the chart method and regression equations (Ritzman et al., 2008). Commonly used methods based on modern population samples, such as the previously discussed chart method, have produced age estimates that were considerably younger than the precise ages and duration of stress episodes obtained through microstructural analysis of archaeological samples (Ritzman et al., 2008). This can greatly affect how early childhood and related events (i.e. weaning) are interpreted by biological anthropologists.

Despite these difficulties, research has continued to explore the timing of EH's. Lukacs (2001) measured defect locations in non-human primates and converted these measurements into approximate age at insult. Hypoplastic defects were more prevalent in the middle and cervical thirds of tooth enamel, and it was concluded that these were likely the result of physiological stresses associated with birth and the postnatal environment (Lukacs, 2001).

In response to problems related to non-linear rates of enamel deposition and the appropriateness of applying modern dental eruption patterns to archaeological populations, researchers have turned to histological analyses of internal enamel defects to explore the pattern and timing of stressors. Microstructural analysis involves the examination of a tooth or tooth sections under a microscope in order to observe the enamel microstructures. Each defect can be assigned to an age at which the defect was recorded in the enamel by counting the brown striae (interior enamel) or perikymata (exterior enamel). According to FitzGerald and co-workers (2006), histological analysis is capable of producing very precise ages of defect formation and duration. However, despite the benefit of increased precision, there have been few microscopic studies to determine EH timing (e.g., Boyde, 1963; Condon and Rose, 1992; FitzGerald et al., 2006; Hillson, 1992a; Hillson et al., 1999; King et al., 2002; Reid and Dean, 2000; Reid et al., 1998). The study conducted by Hillson (1992a) microscopically examined enamel surfaces of an archaeological sample and was able to determine the age at which enamel defects occurred. Hillson (1992a) did note that high levels of cuspal and lateral attrition could reduce the effectiveness of this method. Other studies attempted to match defects occurring on different tooth types to a single stress event within individual dentitions (e.g., Boyde, 1963; Condon and Rose, 1992; Hillson, 1992b; Hillson et al., 1999; Reid et al., 1998).

Internal enamel defects (WB's) can be distinguished from normal brown striae, first discovered by Soggnaes (1956), when teeth are sliced for histological microscopic examination (Gustafson and Gustafson, 1967; Rose et al., 1978;

Wilson and Schroff, 1970). According to FitzGerald and co-workers (2006), the precise age at occurrence and duration of each stress event can be determined through histological analysis. By utilizing the brown striae as incremental growth markers, FitzGerald and colleagues (2006) were able to analyze defect occurrence in biweekly intervals. This strongly contrasts with the biyearly intervals utilized in the Goodman et al. (1980) chart method. The primary drawback, however, to histological methods is that they are destructive to the specimen since the teeth must be sectioned in order to view the internal structures of the tooth.

The Study of Enamel Hypoplasias to Reconstruct Past Health – Capabilities and Limitations

The macroscopic analysis of EH's has several advantages. First, the nature of teeth makes them ideal for study; they are usually well preserved in archaeological contexts. Tooth enamel also undergoes very little diagenetic alteration in the postmortem environment.

Second, this technique is a non-destructive method. Destructive methods are not always feasible when studying archaeological specimens. It should also be noted that non-destructive techniques can be just as reliable and valuable as other more destructive procedures, such as thin-sectioning of teeth for microstructural analysis. According to King and colleagues (2002:38), "…non-destructive technique[s] can be used to generate a detailed and complete sequence of enamel defects formed during the period of crown surface enamel formation".

A third advantage is the fact that chronologically developing dental enamel does not remodel; therefore, the enamel archives developmental stress (Goodman and Rose, 1990). These growth disruptions can be timed when defect locations are measured and converted to estimates of age following standardized developmental schedules (but see the limitations of this method, discussed in the previous section). Disruptions can therefore be documented during particular periods in early childhood (when tooth crowns are forming).

Fourth, the relative ease of EH study is advantageous. Field research can be conducted with little more than visual observation and calipers. The analysis of EH's is more efficient and economical when compared to other, more labor intensive and technologically dependent methods.

Despite the inherent benefits of using EH's to explore the overall health and stress events in a population, there are some limitations that must be recognized. The first inherent difficulty concerns tooth crown development and the nature of dental enamel deposition. Enamel deposition is not linear in the deciduous dentition (FitzGerald and Saunders, 2005; Shellis, 1984) or the permanent dentition (Beynon et al., 1991; Beynon and Reid, 1987; FitzGerald, 1995; Hillson and Bond, 1997; Reid and Dean, 2000). Furthermore, King and colleagues (2002) argued that the appositional enamel found on occlusal surfaces actually hides enamel defects situated in previously deposited layers. During the earlier stages of enamel deposition, layers of enamel are laid on top of one another (see Figure 1), while deposits later in crown development only partially cover earlier enamel layers. According to Hillson and Bond (1997), the occlusal surface of a molar can represent as much as 40-50% of development time. This suggests that the prevalence of enamel defects is underestimated if only the surface defects are examined.

A second difficulty is that even when EH's are easily observable, they may be very difficult to match with a specific stress event (e.g., Fujita, 1939; Gustafson, 1955; Gustafson and Gustafson, 1967). Enamel hypoplasias are often referred to as non-specific stress indicators, which means that they are generalized responses that cannot be connected with specific causal mechanisms. Even when an individual's health history is known, researchers have had a great degree of difficulty matching medical history to this non-specific stress response (e.g., Sarnat, 1940; Sarnat and Schour, 1941). However, EH's can be useful for inferences about general health and quality of life. It is interesting to note that some suggest that hypoplastic defects represent an individual's ability to cope with these biological and physiological stresses; rather than serving as an indication of poor health, these defects demonstrate individual resilience to environmental pressures (e.g., Wood et al., 1992). In other words, an individual must be able to survive the incident in order to exhibit the enamel defect.

A related third concern involves questions of stress severity and duration. Some have suggested that stress severity could be indicated by the depth of an enamel defect while its duration could be determined from the width (e.g., Blakey, 1981; Blakey and Armelagos, 1985; Clarke, 1978; Ensor and Irish, 1995; Hoover et al., 2005; Hutchinson and Larsen, 1988; Larsen and Hutchinson, 1992; Sarnat and Schour, 1941, 1942). FitzGerald and Saunders (2005), however, argued that macroscopic defects underestimate the true level of stress and that microscopic internal defects are more plentiful. This suggests that not all stressors are severe (or long) enough to manifest on the external surface of the tooth. This is consistent with Hillson and Bond's (1997) contention that the differences between the number of macroscopic and microscopic defects were more closely related to the nature of crown development and the defect's position on the crown. Furthermore, it has been demonstrated that spacing between perikymata is greater near the occlusal edge than at the tooth crown cervix and, as a result, EH's are more readily seen near the cervix than at the occlusal edge of the tooth (Hillson, 2005; King et al., 2002). It must be remembered that the occlusal edge of a tooth represents the earlier stages of life and if this information is unavailable due to wear, researchers lose a great deal of potentially important data (Dobney and Ervynck, 2000). In addition, King and co-workers (2002) previously hypothesized that the appearance of an enamel defect was more closely linked to the defect position on the tooth crown rather than the stress duration. More recently, however, Hubbard and co-workers (2009) stated that the total number of perikymata found within a defect was more strongly correlated with the defect width than the defect location or tooth type (valuable for inter-population comparisons), which complicates hypoplasia analysis further.

A fourth concern is the difficulty presented by tooth wear resulting from physical and chemical abrasion. The tooth crown wears as the enamel surface of a tooth comes into contact with the physical environment. Perikymata are gradually worn away by means of this erosion. As a result, EH's can become indecipherable. Although EH's cannot indicate the specific cause(s) of the stress, their prevalence, distribution, and timing can provide valuable information about differential health status within a population (e.g., males versus females) or as a comparative indication of general levels of health between different populations.

The Analysis of Enamel Hypoplasias in Bioarchaeology

Generalized studies of enamel defects have been conducted on non-human primates (e.g., Guatelli-Steinberg, 2000, 2001, 2003; Guatelli-Steinberg and Benderlioglu, 2006; Guatelli-Steinberg and Lukacs, 1998, 1999; Guatelli-Steinberg and Skinner, 2000; Miles and Grigson, 1990; Newell et al., 2006) and swine (e.g., Dobney and Ervynck, 2000). Other research has attempted to link EH occurrence to particular physiological stressors such as fever in rats (e.g., Kreshover and Clough, 1953), diabetes in rats (e.g., Kreshover et al., 1953), inoculation with pathogenic viruses in rabbits and mice (e.g., Kreshover et al., 1954; Kreshover and Hancock, 1956, respectively), and vitamin A and D deficiency in dogs (e.g., Mellanby, 1929, 1930, 1934), among others. Other research has explored EH's in *Australopithecinae* (e.g., Robinson, 1956), *Sinanthropus pekinensis* (e.g., Weidenreich, 1937), early hominids (e.g., White, 1978), Neanderthals (e.g., Ogilvie et al., 1989), and prehistoric humans (e.g., Brabant et al., 1961; Brothwell, 1959, 1963; Corruccini et al., 1985; Hartweg, 1945), as well as enamel development and morphology in Plio-Pleistocene samples (e.g., Guatelli-Steinberg, 2003).

These defects have been widely used to study the health of past human populations in the New World (e.g., Berbesque and Doran, 2008; Cook, 1984; Corruccini et al., 1982; Goodman et al., 1980, 1987, 1991; Infante and Gillespie, 1974), and in the Old World (e.g., Belcastro et al., 2007; Cucina et al., 2006; Guatelli-Steinberg, 2003; Hoover, 2001; Hoover et al., 2005; Mack and Coppa, 1992; Manzi et al., 1999; Ogilvie et al., 1989, among others).

North American studies have tended to concentrate on the transition from hunting-gathering to agriculturalist societies (e.g. Cook, 1984; Goodman et al., 1980, 1984a, 1984b; Hutchinson et al., 1997; Larsen, 1995; Rose, 1977; Sciulli, 1977, 1978; Smith et al., 1984) and have suggested that an increase in the prevalence of hypoplastic defects is associated with the transition to sedentism and agriculture. There are a number of possible features of agricultural communities that may explain the increase in hypoplastic defects. The spread of disease is often associated with increased population density and the decline of hygienic conditions. Food shortages can also affect sedentary agricultural populations that rely on a few select crops. In periods of drought or disease, these crops can fail and dramatically impact the population that relies on them. In contrast, Cook (1984) found little evidence to link LEH with maize intensification. Cook (1984) suggested that previously reported high LEH levels (e.g., Rose, 1977) may have been due to other unclear environmental, temporal, or cultural differences between groups.

Studies of Enamel Hypoplasias in pre-Roman and Roman Period Skeletal Samples

Both Cucina and associates (1999) and Cucina (2002) examined LEH in a prehistoric sample from Trentino, Italy (northern Italy) from the Neolithic (ca. 3000 to 2500 B.C.) to the Early Bronze Age (ca. 1800 to 1550 B.C.). Dental traits demonstrated strong homogeneity while LEH frequency increased through time, which the authors attributed to an increase in sedentism as a result of increased agricultural activities and pastoralism (Cucina, 2002; Cucina et al., 1999). Sedentary agricultural lifestyles may put populations at risk through mechanisms such as malnutrition and the prevalence of contagious disease, as previously discussed. Tafuri et al. (2003) examined skeletal material from the Bronze Age (1800 to 1200 B.C.) site of Sant'Abbondio, Italy (southern Italy), and reported that this homogeneous skeletal assemblage is the only human paleobiological evidence of this period from Campania. The authors found a low overall individual frequency of LEH (51%), which was equally distributed among male and female adults (Tafuri et al., 2003). Tafuri and associates (2003) also measured hypoplastic incidents and calculated an age range of 3-4 years for the majority of defects.

A study conducted by Lovell and Whyte (1999) utilized Greco-Roman (ca. 332 B.C. to 395 A.D.) skeletal remains from Mendes, Egypt. The authors found a low overall frequency of hypoplastic defects (44%) with the permanent dentition exhibiting the majority of hypoplasias (Lovell and Whyte, 1999). Lovell and Whyte (1999) discussed weaning and nutrition as potential causal mechanisms, specifically undernutrition and vitamin deficiency. However, the authors also proposed causes such as respiratory and gastrointestinal infections, again demonstrating that EH's indicate that there is some kind of stress event experienced by these individuals during their lives, but it is difficult to specifically identify the source (or sources) of these stressors.

FitzGerald and colleagues (2006) conducted the first microscopic defect study of WB's during the first year of life in the deciduous dentition of 127 subadults from Isola Sacra (1st to 3rd centuries A.D.). Wilson Bands that continue beyond the interior of the tooth enamel onto the exterior of the tooth enamel are then referred to as EH's. The authors were able to establish a chronology of dental defects peaking first between 2 and 5 months of age and then again between 6 and 9 months, portraying what they called a "realistic risk profile" for the children of this past population (FitzGerald et al., 2006:187). FitzGerald and co-workers (2006) suggested that the two peaks were related to the introduction of solid food and weaning practices.

This picture of early childhood stress resulting from poor nutrition among Roman populations is further supported by Facchini and colleagues (2004), who investigated EH frequencies in Ravenna (1st to 4th centuries A.D.) and Rimini (2nd

to 4th centuries A.D.) (northern Italy). Enamel hypoplasias were more prevalent in individuals from the Ravenna sample (84%). The authors suggested that nutritional stressors were not the only probable cause; intestinal parasitic infections during growth and outbreaks of malarial infections may have contributed to the high EH frequencies observed in Ravenna since it was situated near swamps (Facchini et al., 2004).

Cucina and co-workers (2006) added to the discussion concerning Roman nutrition and childhood stress by examining LEH from the suburban population of Vallerano near Rome (2nd to 3rd centuries A.D.). Linear enamel hypoplasia frequencies were very high, as found in the previous studies (92.9%). Not only did the authors find enamel defects occurring at early ages (later peaking at 3.0-3.4 years of age and then again at 4.5-4.9 years), but the sample also showed a high number of individuals suffering from multiple stress episodes and dying at an early adult age with few living beyond the age of 50 (Cucina et al., 2006). Cucina and co-workers (2006) suggested that high LEH frequencies were more likely the result of the interaction between malnutrition and disease susceptibility.

Manzi and co-workers (1999) explored living conditions using dental pathology data (including LEH) during the transition from Imperial Rome to the Early Middle Ages utilizing three samples from the areas surrounding Rome; Lucus Feroniae (1st to 3rd centuries A.D.), Isola Sacra (1st to 3rd centuries A.D.), and La Selvicciola (7th century A.D.). Of particular interest in this study is the Lucus Feroniae sample, which was a rural lower class population of manual laborers (i.e., war veterans, slaves, and freemen). Linear enamel hypoplasias frequencies per tooth were highest in the Lucus Feroniae skeletal sample (46 %) when compared to the other two samples (Manzi et al., 1999). A high rate of Roman infant mortality was observed with a peak of hypoplastic defects occurring during the first two years of life, and the authors interpreted this data as evidence of decreased immunological benefits as a result of a young weaning age (Manzi et al., 1999).

Living conditions and metabolic stressors in two Roman skeletal samples, Casalecchio di Reno (2nd to 5th centuries A.D.) (near Bologna) and Quadrella (1st to 4th centuries A.D.) (near Molise), were examined by Belcastro and co-workers (2004). The researchers reported high frequency of LEH in both samples, and although the per tooth LEH frequencies were statistically higher in the Quadrella sample, the LEH frequencies per individual were comparable in both populations (93% at Casalecchio di Reno and 95% at Quadrella, respectively) (Belcastro et al., 2004). Poor nutrition and high amounts of childhood stress in Italy during the 1st to 5th centuries A.D. were inferred from the high frequency of enamel defects (Belcastro et al., 2004).

Hoover and associates (2005) explored the relationship between odontometric asymmetry and enamel hypoplasias as evidence of childhood stress in a skeletal sample from Isola Sacra (1st to 3rd centuries A.D.) (near Rome). This study found only a weak relationship between the two physiological responses, suggesting that more complex factors (i.e., genetic, multiple causal mechanisms) may also influence these responses (Hoover et al., 2005).

In a subsequent paper, Belcastro and colleagues (2007) compared LEH frequencies from Quadrella and Vicenne-Campochiaro (6^{th} to 8^{th} centuries A.D.). As previously stated, the population at Quadrella exhibited very high rates of LEH frequency per individual (95.2%). However, the individual frequency of LEH was extremely high in the sample from Vicenne-Campochiaro (100.0%). The authors concluded that the high frequencies of LEH in both of samples seemed to support the existence of powerful metabolic stress during early periods of childhood, possibly a result of typical Roman weaning and dietary practices (Belcastro et al., 2007).

In a recent study, Paine and co-workers (2009) examined rural middle class remains from two coeval *necropoli* at Urbino (1^{st} to 3^{rd} centuries A.D.), located in central Italy. The population at Urbino exhibited extremely high rates of LEH frequency per individual (100%) (Paine et al., 2009). The authors contributed this high frequency to an extremely poor quality of life for the sample at Urbino (Paine et al., 2009).

The majority of previous hypoplasia studies of Roman period skeletal samples have found relatively high percentages of individuals affected by EH’s (e.g., Belcastro et al., 2004, 2007; Cucina et al., 2006; Facchini et al., 2004; Paine et al., 2009). This would seem to suggest that Roman period populations may have been chronically stressed at a young age (i.e., infancy and childhood). This study will test the hypothesis utilizing a sample from the Roman site of Vagnari.

TABLE 1: Cuspal Development Time According to Tooth Type (after Hillson, 1996)

Tooth Type	**Number of Years (approximately)**
Central Incisor	3.5
Lateral Incisor	3.75
Canine	5.5
Premolar	4.0
1st Molar	4.25
2nd Molar	5.0
3rd Molar (maxillary)	3.0 – 6.0
3rd Molar (mandibular)	2.0 – 5.0

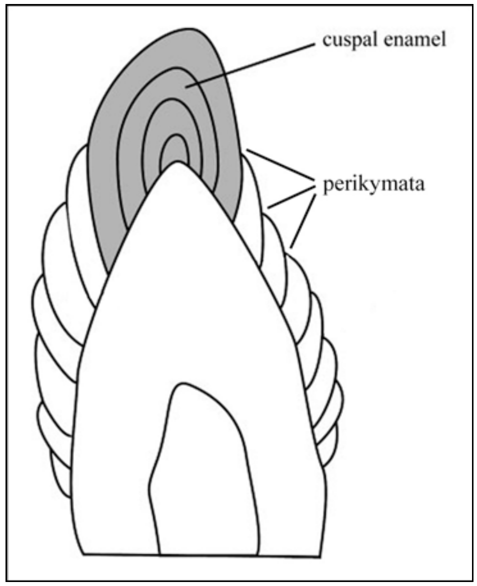

Fig. 1. An illustration of an incisor crown demonstrating cuspal enamel deposition. Adapted from Ritzman et al. (2008:349) after Aiello and Dean (1990). This article was published in "Introduction to Human Evolutionary Anatomy", Aiello and Dean, Page No 112, Copyright Elsevier (1990).

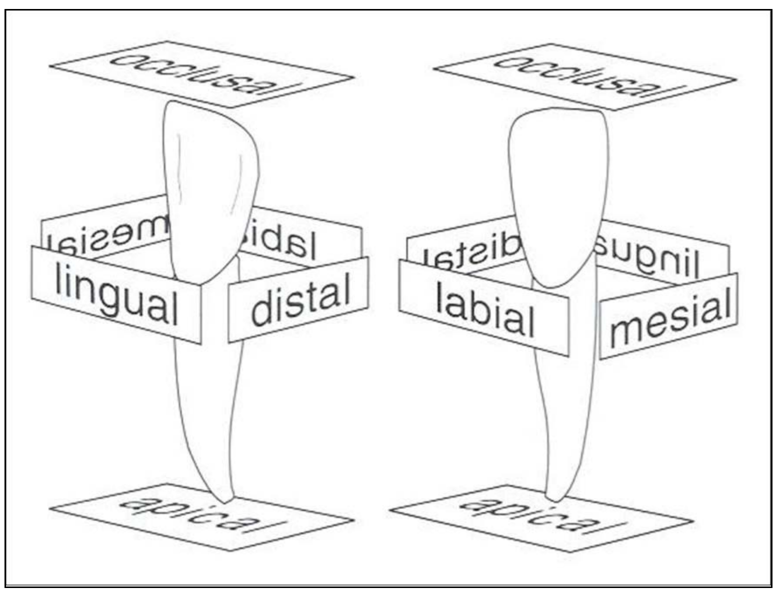

Fig. 2. Anatomical planes of a tooth. This article was published in "The Human Bone Manual", White and Folkens, Page No 130, Copyright Elsevier (2005).

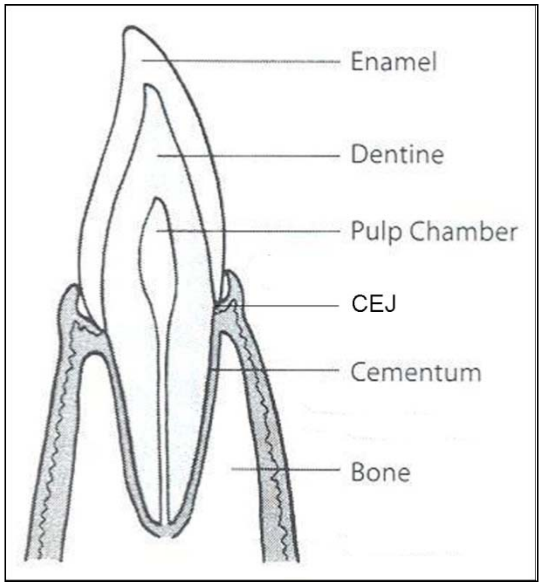

Fig. 3. An illustration of tooth anatomy. Adapted from White and Folkens (2005). This article was published in "The Human Bone Manual", White and Folkens, Page No 130, Copyright Elsevier (2005).

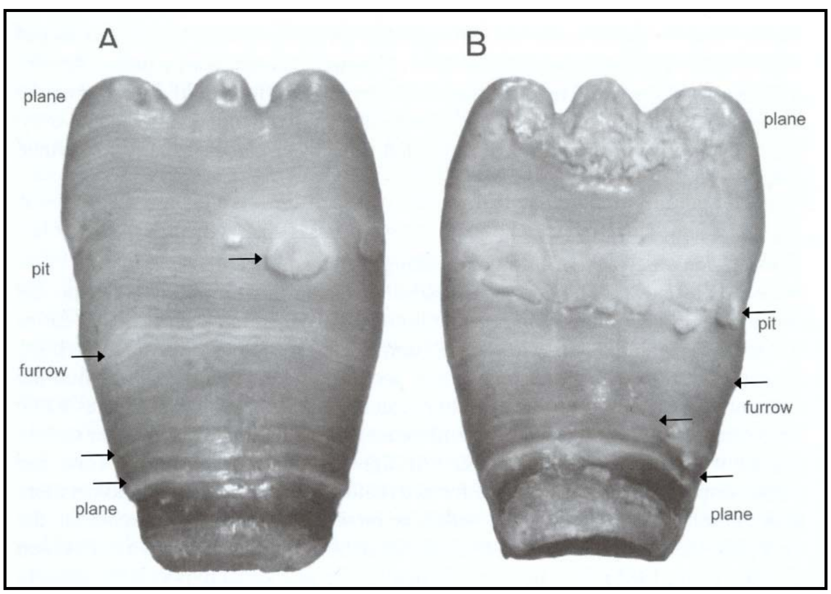

Fig. 4. Permanent lower central incisor. Image A is the labial surface and Image B is the lingual surface of the same tooth. Multiple linear pit EH's are marked with an arrow near the middle of the crown and three pronounced LEH's are indicated below the linear array pits. Adapted from Hillson (2005:170). Reprinted with the permission of Cambridge University Press.

Fig. 5. Cast of permanent left maxillary canine, premolars, and first molar from Vagnari individual F137A. Multiple LEH episodes are visible on the labial surface of all teeth.

CHAPTER 3

HISTORICAL BACKGROUND –
VAGNARI AND ITS CONNECTION TO THE ROMAN EMPIRE

Rome's first king, Romulus, was thought to have founded the city on April 21, 753 B.C. Although 753 B.C. was a commonly accepted founding date, recent archeological investigations in Rome and central Italy suggest that this area has been continuously occupied since the late Bronze Age (1200 to 1000 B.C.) (Cornell, 1995; Ward et al., 2003). This founding period was known as the Regal (or Monarchy) Period during which Rome was ruled by a kingship. The Roman Republic followed in 509 B.C. and was famous for its public assemblies and the senate, a body of advisors composed of current and former public officials. The Roman Empire began with the Emperor Augustus in 27 B.C. and persisted until the early 7th century A.D. The site of Vagnari was occupied from the 4th century B.C. until the 6th century A.D., while the cemetery was in use from the late 1st to 4th centuries A.D. Much of the following review is drawn from Ward and colleagues (2003), unless otherwise noted.

The Rise and Expansion of the Roman Empire in Italy

On or around 350 B.C., Rome had exerted its control over central Italy and began to look South; this meant contending with the numerous local populations that controlled various regions of southern Italy, including the Samnites, Lucanians, and the Peucetii. A paramount strategy to gain powerful allies was implemented in 348 B.C., which renegotiated a previous treaty with Carthage, Tunis. The Carthaginians were granted permission to attack any non-Roman allies along the western coastline of the Italian peninsula. Rome also agreed to not found colonies or conduct independent trade in Carthaginian-controlled lands, both within and outside of the Italian peninsula. The Romans had also negotiated an alliance treaty with the Samnite people in 354 B.C., who occupied Campania and controlled the towns of Capua and Cumae. However, Rome's increasing need for territorial expansion eventually caused the alliance with the Samnites to crumble.

The Samnites were one of several tribes neighboring ancient Rome (600 B.C. to 290 B.C.). They had conquered the Greek Oenotrians (11^{th} to 5^{th} centuries B.C.) who had settled a territory that included the regions of Apulia, Basilicata, and the northern part of Calabria in southern Italy. The Samnites' growing population and resource demands required continual expansion of their territory. Many wars were fought with their neighboring tribes, including Rome, over land rights in central Italy. In fact, even major Greek colonies such as

Taranto in southern Italy were becoming concerned about the ever-expanding Samnite borders (Ward et al., 2003).

The Lucanians were a southern division of the Samnite tribe, controlling an area of southern Italy that extended from the Tyrrheanian Sea to the Gulf of Taranto from the mid-5th century B.C. to 272 B.C. At one point, the Lucanians held control of the entire Italian peninsula south of the Samnite territory except for the coastal Greek towns. Insurrection broke out among the native people and the Lucanians were defeated and retreated back to their original territory.

In addition to the Samnite tribes, the Iapygian (Indo-European) Peucetii (also known as the *Poedicli*) tribe lived in the Apulia region of southern Italy. The cities of Canosa, Bitonto (the modern capital of Apulia), and Silvium were founded by the Peucetii. In Vinson's 1972 report, he stated that Gravina was probably the ancient city of Silvium (Vinson, 1972). This has since been refuted by Small (2001), who hypothesized that the city was actually located on the Late Iron Age hilltop of Botromagno, which is only a few kilometers away from Vagnari. This territory was of geographical and political significance, as it contained the only road connecting Brindisi and Benevento (Strabo, *Geographica* VI.3).

The Peucetii were culturally a part of *Magna Graecia* (Latin, "Greater Greece"), which was the name of the Tyrrheanian coastal area that was heavily colonized by Greek settlers in the 8th century B.C. These immigrants brought their Hellenic culture, which blended with the local traditions and left a lasting mark on southern Italy. Greece lost this strategically located territory when

Magna Graecia was absorbed by the ever-expanding Roman Republic after the Pyrrhic War (282 to 272 B.C.).

Civil War in Italy during the Roman Republic (509 to 27 B.C.)

Much of the history of southern Italy during the Roman Republic period (509 to 27 B.C.) was characterized by a succession of civil wars between neighboring tribes as a result of territorial expansion and control. The southern Italian site of Botromagno fell under Samnite control in the late 4th century B.C. at the same time that we have the earliest traces of occupation at the site of Vagnari. The Romans later captured the settlement in 306 B.C. after a siege and the partial abandonment of Botromagno, which has been supported by archaeological findings (Small, 2001).

At the onset of the First Samnite War (343 to 341 B.C.), the Samnites advanced on Sindici, located on the northern border of Capua's territory in Campania, around 343 B.C. The Capuans requested assistance from Rome, who readily provided aide to what was then Italy's second largest city. When the Samnites took occupation of the Sidicini territory in 340 B.C., the Latins and Campanians took up arms to defend the land. This insubordination resulted in warring between the Latins, Campanians, and Rome. In 338 B.C., the Latins were crushed while the Campanians accepted a generous peace treaty from Rome.

Friction had been building since 341 B.C. between the Samnites and Rome concerning westward expansion of the Samnite territory. The Second Samnite War (327 to 304/3 B.C.) was declared after a dispute in Naples. The most famous battle occurred in 321 B.C. when the Samnites trapped the Roman army in the Caudine Forks mountain pass in a range located between Campania and Apulia. The Romans were forced to surrender and agree to peace terms. Despite this humiliation, after the Romans had reformulated their mountain military tactics, they renewed the war in 316 B.C.

Appius Claudius Caecus suggested that the Romans force the Etruscans, with whom the Samnites sought to form an alliance, to honor their previous treaties with Rome. Caecus also masterminded the construction of a highway that extended from Rome to Capua in order to swiftly move soldiers between the cities. This came to be known as the Appian Way (*Via Appia*) (see Figure 6). The Appian Way, which was the first major paved road of Rome, and Rome's first aqueduct were constructed in 312 B.C. According to Ward and colleagues (2003), Roman conquests of central and southern Italy provided wealth that financed many such major public improvement projects. Despite these strategic moves, the peace of 304/3 B.C. had indicated no clear victory.

In 298 B.C., the Lucanians made an alliance with Rome, which was broken shortly thereafter. Faced with the growing power of Rome, the Etruscans, Umbrians, and Gauls (who occupied the Po Valley in northern Italy) joined the Samnites in an attempt to push back the Roman boundaries during the Third Samnite War (298 to 290 B.C.). The victories of Manius Curius Dentatus won central Italy for the Romans in 290 B.C. The Samnites eventually surrendered and their lands were annexed into Rome. The Romans then established Venosa, a colony located on the Apulian border. The Roman victory against the Samnites had removed a strong buffer between Taranto, the most powerful Greek city-state (*polis*) in southern Italy, and the ever-expanding Roman territory. At the onset of the Pyrrhic Wars (282 to 272 B.C.), the Greek general Pyrrhus ambitiously attempted an attack on the city of Rome but was stopped near Praeneste, about 64 km outside of the city.

In 278 B.C., the army of Pyrrhus was called to aid Sicily against the Carthaginians. Part of Pyrrhus' naval fleet was lost during a sea battle with the Carthaginians in 276 B.C. Continued resistance in Italy forced Pyrrhus to return to Greece in 275 B.C., leaving a small garrison in Taranto. The garrison was removed in 272 B.C. when the Lucanians were defeated. Pyrrhus died in battle near Argos later that year.

This final victory over Pyrrhus clearly brought attention to the fact that Rome was now a major power in the Mediterranean. Ptolemy II of Egypt sought alliance with Rome in 273 B.C. After the Etruscan city of Orvieto was crushed after an attempt to rebel in 264 B.C., it was clear that all of peninsular Italy was under Roman control. Ward and colleagues (2003) compared this outward movement of centralized Roman power as analogous to "…ever-widening ripples from a stone dropped in a quiet pool" (93).

Civil strife in Italy continued during the Punic Wars (264 to 146 B.C.). In 216 B.C., the Roman army of 80,000 men marched to meet Hannibal, the military leader of Carthage, at Cannae, a small Apulian fortress town. While Hannibal had only half the soldiers, his superior military tactics left the Romans with only 15,000 men; approximately 80% had been killed or captured during the battle (Ward et al., 2003). In the years to follow, Capua in Campania and Syracuse in Sicily broke their allegiances with Rome in order to join Hannibal. Taranto fell under Hannibal's control in 213 B.C. Rome responded by trying to win back the cities that had allied with Hannibal while maintaining their current allegiances; their goal being to isolate Hannibal from resources and military reinforcement. Rome eventually won back their disloyal cities and returned all of Campania to Roman control. In 209 B.C., Taranto was reoccupied by Rome. Those who had allied with Hannibal were forced to relinquish their lands to Rome as punishment for their disloyalty.

The years of civil war had ravaged the Italian peninsula. The Lucanians and Peucetti fell to Rome during the Second Punic War (216 B.C.). Archaeological evidence corroborates a tumultuous third century at the Basentello Valley settlements of Botromagno and Monte Irsi (Small, 2001). Regional archaeological survey has not discovered any pot sherds dating to the 3rd century at these sites (Small, 2001). Pottery fragments dating to more recent times (2nd and 1st centuries B.C.) have been attributed to later site re-occupation (Small, 2001). According to Small (2001), these interruptions of site occupation were likely a result of the Hannibalic War.

While farmers were away at war, their lands were devastated by the movement of armies and supplies (Thompson, 2003; Ward et al., 2003). The

Lucanian and Peucetian territories had been ravaged during the course of several campaigns and, under Roman rule, remained in a state of disrepair. Famine had become widespread and supplies were scarce (Ward et al., 2003). The Lucanians briefly joined the Samnites during the Social War (90 to 88 B.C.) but were quickly subdued by Rome. The settlements on Botromagno and Monte Irsi were largely abandoned by the 1st century B.C. (Small, 2001). As farmers failed to return to work their land and, with rural populations declining, the establishment of large rural estates (*latifundia*) held by the wealthy landowners became more common (Thompson, 2003).

Stability in Italy During the Roman Empire (27 B.C. to 235 A.D.)

The first period of the Roman Empire, which extended from the beginning of the reign of Augustus until the assassination of Severus Alexander in 235 A.D. is known as the Principate. Under Augustan rule (27 B.C. to 14 A.D.), civil war ended and an extensive road system was constructed across Italy. Agriculture, industry, and commerce blossomed as a result of the overall level of tranquility and increased possibility for communications between regions. The economic success of the Augustan reign is indicated by the construction of the Roman Coliseum, originally the Flavian Amphitheatre, in 70 A.D. (see Figure 7). Urban expansion such as this was made possible by increased employment possibilities and amenities (Temin, 2006; Ward et al., 2003).

In southern Italy, this period of stability under the rule of Augustus is evidenced by attempts to re-occupy the settlements on Botromagno (mid-2nd century A.D.) and Monte Irsi (mid-1st century A.D.), although each of these were short lived (Small, 2001). In contrast to these brief periods of activity, the north-west slope of Serra San Felice was settled and developed into a flourishing villa during the Imperial Period (Small, 2001). In addition, other sites were founded and existing sites began to expand. The first major phase of occupation started at Vagnari in the 1st century A.D. This trend continued for a considerable amount of time until about the middle of the 6th century A.D. (Small, 2001).

Imperial consolidation and warfare under Augustus brought large numbers of slaves into the Roman Empire (Casson, 1998). By the end of the reign of Augustus, modern Spain, Portugal, Switzerland, Bavaria, Austria, Slovenia, Albania, Croatia, Hungary, Serbia, Syria, and parts of northern Africa had fallen to Rome (Eck, 2003). The ancient historians Cato (234 to 149 B.C.) and Varro (116 to 27 B.C.) suggested that slaves were the chief form of labor on large rural estates during this time, in addition to paid laborers and craftsmen that were hired as needed (Thompson, 2003). Although literary sources such as Cato and Varro discuss slaves, the direct evidence of slavery is fairly limited. Thompson (2003) suggested that rural architecture could provide plans of houses in which slave-quarters could be inferred. Rural villas likely to own slaves were large, wealthy homes containing many rooms arranged around a central courtyard or multiple courtyards (Thompson, 2003). The slave quarters (*cellae*) were small bare cublicles and were commonly arranged in rows or groupings (*cellae* *familiae*). Many times the floors would be unpaved and the walls unplastered (Thompson, 2003).

Augustus was cognizant of the possibility for massive slave revolts (such as those in the Late Republic) and promoted the humane treatment of slaves. Under his reign, slaves were given the right to voice their concerns and complaints to an established urban prefect. After all, slaves and freedmen were critical to professions in industries such as farm management (*vilicus*), grain supply (*cura annonae*), grain dole (*frumentatio*), water supply (*cura aquae*) and control (*cura riparum et alvei Tiberis*), the mint (*moneta*), and the Military Treasury (*aerarium militare*); their presence greatly benefitted the Empire (Casson, 1998; Temin, 2006; Thompson, 2003; Ward et al., 2003).

Roman slavery is often referred to as “open” slavery by anthropologists, meaning slavery in which slaves could be freed and become fully accepted members of society (Temin, 2006). A distinguishing feature of Roman slavery was the opportunity for manumission (or freeing) as a result of hard work, skill, and monetary earnings (*peculium*), with which slaves could negotiate their freedom (Casson, 1998; Temin, 2006). According to Scheidel (1997), nearly 10% of slaves over the age of 25 were freed every five years in the Early Empire.

Augustus rewarded cooperative freed slaves (*freedmen*) and even created posts for them to compensate for their lack full citizenship. In fact, certain freedmen acted as managerial agents for the emperor by receiving petitions and requests from Romans across the Empire. This discretionary power allowed these freedmen to gain real public influence, privilege, and status that had never been available during the Republic (Ward et al., 2003). Aware of the powers that came with freedom and Roman citizenship, Augustus imposed restrictions and taxes on slave owners who wished to free their slaves (Ward et al., 2003). Furthermore, freedom could never be granted to a slave that had been imprisoned.

After the reign of Augusts, the period of the “five good emperors” followed from 96 to 180 A.D. (Ward et al., 2003). According to Ward and colleagues (2003), this designation was not intended to suggest that previous emperors had not been “good” but that the emperors Nerva, Trajan, Hadrian, Antoninus Pius, and Marcus Aurelius comformed to the ancient ideals in comparison to other rulers. According to Ward and co-authors (2003:335), few natural disasters or military issues occurred during this period, which added to the apparent success of the “good” emperors.

Trajan (98 to 117 A.D.) is remembered for pursuing many enlightened social and economic agendas which added to the prosperity and appeal of Rome. Trajan strove to improve provincial conditions and communications by ensuring that roads, bridges, harbors, and aqueducts were built or revitalized in every province. Finally, the Empire was extended under Trajan during the Trajan Wars (101 to 102 A.D. and 105 to 106 A.D.), but had been weakened in the process since Rome was unable to defend its newly expanded territory.

After the reign of Marcus Aurelius (161 to 180 A.D.), the golden age of the Roman Empire was drawing to a close and was leaving some underlying problems for those who would follow the “five good emperors”; unregulated territorial expansion left the military with unfeasible defensive burdens, the centralization of political power was not able to respond quickly to a crisis in isolated regions, and the military wielded the power and ability to control the state. The occupation of the northern part of Vagnari declined during this period and use of this area ceased in the 3rd century A.D., with a shift in occupation to the southern part of the site (Small and Small, 2005).

Rome radiated power throughout the Empire and became a centralized location for commerce and culture. However, Italy declined as a production center since products moved freely throughout the Roman Empire. Fortunately only spoilage-resistant agricultural products (i.e., grain, oils, and wine) could move long distances, so the majority of food production tended to remain localized. Efforts to improve public works and alleviate real hardships (i.e., provision of grains, improvement of housing conditions, flood control, water supply, and sanitation) were undertaken by the emperors and wealthy local benefactors. The Empire reached great social and economic heights allowing the peninsula of Italy to experience relative peace and prosperity while military threats on the frontiers were usually contained.

The third century A.D. of Rome began after the death of Marcus Aurelius in 180 A.D. It can be divided into two parts. The first extends from the death of Marcus Aurelius in 180 A.D. until the assassination of Severus Alexander in 235 A.D. During this time, the Empire experienced relative internal peace except for two political crises (193 to 197 A.D. and 217 to 221 A.D.). The second part, known as the Dominate, spans the period after Severus Alexander's assassination in 235 A.D. to the victory of Diocletian in 285 A.D. It is characterized as a period of tumultuous ruling.

Crisis in Italy during the Roman Empire (235 to 285 A.D.)

The Principate was quickly becoming an absolute monarchy that relied on military power for support. Frequent civil wars and political assassinations saw the rapid succession of twenty-six emperors and constant battles along the frontiers during the latter half of the 3rd century. The pressure of these stressors in addition to an outbreak of a plague (Plague of Cyprian, 251 A.D.) nearly led to a split of the Empire. The plague had a staggering death toll and, at the height of the epidemic, it is estimated that as many as 5000 people died in the city of Rome each day (Ward et al., 2003). The high death toll left the Roman Empire with a shortage of laborers (both urban and rural). Eventually, the Roman Empire had become so unmanageable that Diocletian (284 to 305 A.D.) split control into the Eastern and Western Empires; each with its own emperor.

Agricultural and industrial production was low due to decreased man power and resources. The once well-maintained road systems were in a state of disrepair making transportation and communication difficult. The Roman Empire could not supply enough men or finance the expansive defensive military fronts. Farmers suffered from thefts and requisitions of their fields and livestock by bands of thieves and even passing Roman armies. According to Ward and colleagues (2003:405), the result of such pressures was that "…land, particularly of marginal quality or on unstable frontiers, went out of production". As defenses drained resources, many citizens sank into positions of "suffering subjects" (Ward et al., 2003).

Inflation was said to have increased by as much as 700% between the years of 267 to 274 A.D., but did not affect all citizens equally (Ward et al., 2003). About 90% of the Empire's population lived in the countryside and were able to avoid such inflation through trade and barter systems of commerce. However, the taxes imposed upon farmers took a heavy toll on their limited incomes.

By the end of the 4^{th} century A.D., emperors served as mere figureheads while military leaders became the effective rulers of the Empire. In addition, the divide between economic classes had become vast. The condition for the middle and lower classes continued to deteriorate during this period as the government continued to draw funding, labor, and supplies from them. The majority of lower classes were residing in the country as tenant (*coloni*) farmers on great estates, similar to those found at the site of Vagnari. According to some, the distinction between *coloni* and slaves was often blurred as slaves of great estates eventually became more like the tenant farmers (e.g., Temin, 2006; Thompson, 2003; Ward et al., 2003). The cemetery at Vagnari was no longer in use after the 4^{th} century A.D., but the site was occupied until the 6^{th} century A.D.

In 476 A.D., the Western Roman Empire, which included the Italian peninsula, fell to Germanic mercenaries. The Eastern Roman Empire (also known as the Byzantine Empire) persisted and referred to themselves as Romans until 1453 A.D., when Constantinople fell to the Ottoman Turks. In fact, people continued to refer to themselves as Romans in parts of Greece well into the 19th century (David Sutton, personal communication). These Greek people still refer to their written language as “Roman” at present (David Sutton, personal communication).

The Geographic, Political, and Economic Landscape of Apulia

The region around Vagnari lies within an area with distinct geological features (see Figure 8). *Le Murge* (the Murge), an arid limestone upland, forms the north-eastern boundary of this territory (see Figure 9). Rainwater is generally absorbed by the underlying bedrock, leaving the barren plateau suitable for grazing sheep but less than ideal for crop cultivation (Small, 1991). The *Murge* is along a major fault line that distinguishes the western and south-western edge of the plateau. South and west of the fault lay fertile lowlands known as the *Fossa Bradanica* which is about 300-400 meters above sea-level, comprised of sandy clays and marine limestone (locally known as *tufa*), and cut by numerous watercourses (see Figure 8). The majority of the channels in this system remain dry for much of the year. The Basentello Valley is located within the *Fossa Bradanica*. According to Small (1991), this valley has been primarily cultivated with grain since the late Middle Ages. The hills of the valley have supported crops of olives, grapes, and cereals (Small, 1991). The Basentello river, which flows south-east, forms the southern border of the territory (Vinson, 1972). The Lucanian Apennines form the western boundary.

The geology of the *Murge*, *Fossa Bradanica*, and the Apennines has influenced the path of major roads, including the *Via Appia*, so that they run in a north-west to south-east direction (Vinson, 1972). In fact, most of the valleys follow the axis of the Italian peninsula, running north-west to south-east, making communications across (i.e., west to east) the peninsula difficult (Small, 1998; Small, 2001). In the Roman period, an important communication route in Puglia connected Bari and Potenza (see Figure 8). The central part of this route was used as a *tratturo*, or drove road for flocks of animals, and led from Silvium to the Apennines in the west (Small et al., 1998; Small, 2001). The *tratturi* (pl. *tratturo*) followed the most passable routes through the hills of the *Murge* and had an important impact on settlement patterns in the Iron Age and Roman period (Small et al., 1998).

The primary road that connected Rome to the south-east coast beginning in the Roman Republic was the *Via Appia*, which ran through the Basentello Valley near the modern city of Gravina (Small, 1991) (see Figures 10 and 11). During the Roman Empire a portion of the *Via Appia* that crossed the Apennines seems to have been abandoned and was replaced by the *Via Appia Traiana*, which followed a more northern route and was thus further removed from the area around Gravina (Small, 1991). It is likely that the abandoned portion of the *Via Appia* following the *Fossa Bradanica* would have continued to have been used since it connected the important sites of Venosa, Taranto, and, eventually, the Ionian Gulf (Small, 1991).

The *Via Traiana* and the *Via Appia* were explored by Thomas Ashby in the early twentieth century. Other studies conducted in the mid-twentieth century followed the course of the *Via Appia* from Venosa to Taranto (e.g., Fedele, 1966; Lugli, 1952). Several authors have provided evidence suggesting that the *Via Appia* has existed, as a road, for a longer period of time than the city of Rome (e.g., Fedele, 1966; Vinson, 1972). It has also been demonstrated that the Romans had utilized pre-existing routes in order to extend the *Via Appia* to Taranto (Fedele, 1966; Vinson, 1972).

The earliest systematic field surveys of significance in southern Italy were conducted by Sterling Vinson in the 1970s. Vinson and his colleagues surveyed at least 550 km^2 and identified about 40 archaeological sites before the advent of modern deep plowing and subsequent destruction of important archaeological evidence (Small, 1991). Vinson (1972) reported that the *Via Appia* likely ran from Venosa to Silvium, following the modern road from Irsina to Gravina, and then continued on to Altamura.

Archaeological evidence suggests that areas of southern Italy have been occupied since the Paleolithic (Mussi, 1986; Palma di Cesnola, 2001). A number of ancient settlements have been discovered along the banks of the major watercourses in the area, which would have provided fresh water and a natural line of defense (Vinson, 1972). During the Early Empire (c. 30 B.C. to 70 A.D.), many of the sites were located on such slopes or on plateaus above the Basentello Valley but none were found on or near the *Murge*. Small (1991) concluded that this evidence suggested agricultural subsistence rather than herding in these site areas, because the *Murge* was commonly used as a pastoral area during the Early Empire.

The hill settlement of Monte Irsi was founded 12 km from Botromagno in the Early Iron Age (c. 8th to 3rd centuries B.C.) (see Figure 12). Small (2001) has suggested that occupation at the site lasted until at least the end of the 3rd century B.C. The presence of a villa during the middle of the 2nd century B.C. suggests that the site of Monte Irsi had come to an end sometime before then (Small, 2001). This settlement was protected by a wall and extended over the entire plateau, an area of approximately 32.5 hectares.

According to Small (2001), Botromagno was a large Peucetian Late Iron Age settlement (c. 6th to 1st centuries B.C.). The site was an ideal settlement location because it was protected by steep scarps (or slopes) on the north, east, and south sides, which provided a form of natural defense. The west side was protected by a man-made defensive wall, which encircled the entire settlement. While the area within the walls was approximately 140 hectares, Small (2001) has suggested that not all of this space was utilized for living areas. Common areas and burial spaces were interspersed within the areas of settlement (Small, 2001). Roman burial spaces were typically situated separately from areas intended for the living.

Archaeological evidence suggests that there were inequalities of wealth and status among the population at Botromagno (Small, 2001). Also, agricultural production must have produced a surplus that could have been traded for imported goods (Small, 2001). Small (2001) suggested that as the Botromagno population increased, there was a pressure to found other settlements across the *Fossa Bradanica*. Enemy invasions would have made defensive strategies necessary, either through defensive mechanisms (i.e., ramparts) or through retreat to a nearby fortified settlement (Small, 2001). Small (2001) hypothesized that cereal cultivation likely increased to support the growing populations, thereby necessitating the clearing of land to expand arable areas.

There are two main phases of occupation on the hilltop and slopes of San Felice. The earlier site is situated on the hilltop plateau of *Serra San Felice* (see Figure 13). The settlement extended approximately 133,000 m^2 and was occupied from the 10th to 3rd centuries B.C. A small part of the site was later occupied in the Middle Ages (Small et al., 1998). The plateau on which the site is located is 500 meters above the Basentello River and is protected along its north-west, south-west, and south (partially) sides by steep scarps. These natural barriers were strengthened by a wall as in Monte Irsi and Botromagno (Small, 2001). As previously discussed, a *tratturo* passed within 200 meters of the southern edge of the site, connecting the *Murge* to the east with the Central Apennines. Small and colleagues (1998) suggested that a moderately sized building may have once existed here to serve as shelter along the road. Loom weights have been found at the site and suggest activities such as wool processing and rough grazing or sheep and goats (Small et al., 1998).

In contrast to the abandonment of the other sites in this region around the 3rd and 2nd centuries B.C., a villa on the western slope of San Felice overlooking the site of Vagnari appears to have been continuously occupied throughout the

Roman Period (Small et al., 1998; Small, 2001). The villa's large size and lack of local competition seem to suggest that it controlled much of the cultivation in the area during the Late Republic (Small et al., 1998; Small and Small, 2007a). According to Small and Small (2007a), the San Felice villa likely became the property of an emperor, who developed a village at Vagnari in the 1st century A.D. and focused on the production of grain and wine (Small et al., 1998).

Roman villas have been studied for over five hundred years; there is more information about villa form and function than any other Roman architectural structure (Dyson, 2003). Both ancient and modern authors use the term "villa" to describe a variety of structures from modest country homes to grand imperial estates, which cause a semantic difficulty for defining the villa. Dyson (2003) describes three villa complex types: the *villa maritima*, *villa suburbana*, and *villa rustica*. Of interest to this paper are the two latter types. The *villa suburbana* was a country residence that offered its owner the freedom of country living with the conveniences and social activities of a city. The *villa rustica* is defined as being located away from the coast and major urban centers. Some *villae* (pl. *villa*) were even more rural than this and were removed from any colony (*colonia*) or municipality (*municipium*). Rural villas managed a variety of production methods including the extraction of natural resources, product manufacturing, and land exploitation. Activities such as forestry, mining, ceramic production, animal husbandry, and agriculture were all carried out by Roman rural villa structures (Dyson, 2003).

Rural land was primarily utilized for agricultural purposes by wealthy landowners during the Roman period. The countryside was worked by independent peasants, leasing tenants, or enslaved individuals (Casson, 1975; Garnsey, 1988, Thompson, 2003). According to Garnsey (1988), the economy of Rome depended on these individuals for food production. In times of shortage, it was these rural lower classes who ultimately suffered (Finley, 1985; Kolendo, 1994; Scott, 1976). Frequent periods of hardship had a strong negative effect on the diets, nutrition, and hygiene of working class Roman populations (Manzi et al., 1999). Infant mortality was between 15-50% during the first year of life in this period (Chamberlain, 1979; Garnsey, 1991; Saller and Kertzer, 1991). At least 50% of children who survived the first year would die before the age of 10 (Garnsey, 1991). Some (e.g., Garnsey, 1991; Harlow and Laurence, 2002; Temin, 2006) have suggested that life expectancy was about 25 years of age while Chamberlain (1979) has claimed that life expectancy may have been around 35 years of age.

As previously stated, agricultural profits were retained by landowners and were rarely fairly redistributed to the workers of the property. According to Cucina et al. (2006:112), this "…indirectly indicates that slaves and tenants used to live in harsh conditions and were the first to suffer from any disadvantageous situations". The diet of the lower class primarily consisted of cereals and other low-cost goods (Prowse et al., 2004), while more costly goods were intended for the commercial markets (Cifarelli and Zaccagnini, 2001). A typical Roman working class meal consisted primarily of grains (sometimes made into bread), vegetables (including olives), wine, fruit, and some animal fats (Brothwell and Brothwell, 1969). Dosi and Schnell (1990) have suggested that foods such as chick peas, onions, and garlic were typical among the lower classes. Other dishes like fish and cheese could be available to the poor, provided that they had access to coastal or pastoral lands (Belcastro et al., 2007). Other types of meat were not considered to be a primary food by ancient Mediterranean populations, so it was consumed on rare, festive occasions (Flandrin and Montanari, 1997).

The Roman countryside was particularly vulnerable both locally and nationally. Estates could fail as a result of local factors such as poor land management, land quality, or harvests (see Cronon, 1983). National factors are more often cited as causes of the decline of the Roman countryside. The rural areas of Rome were vulnerable as the Roman military system weakened and warring barbarians entered the Italian peninsula (Dyson, 2003). Unfortified *villae* and farms were especially exposed to such dangers (Dyson, 2003). Furthermore, Roman soldiers were generally recruited from rural areas during the Republic and Empire, effectively reducing the capable labor and defensive force available on rural farms (Dyson, 2003). During this time, Rome implemented an oppressive tax system to support their military campaigns. The additional financial burden was especially difficult for the already poor peasantry that lived and worked in the rural areas (Dyson, 2003).

The Site of Vagnari

Vagnari (4^{th} century B.C. to 6^{th} century A.D.) is a Roman settlement extending over 3.5 hectares in a side valley of the Basentello River. The location of Vagnari is in close proximity to the *Via Appia*, which followed the northern part of the Basentello River Valley between the cities of Venosa and Silvium (Vinson, 1972), meaning that the settlement of Vagnari had access to communication and transport. The site of Vagnari lies 1.5 km north-west of San Felice; the two sites are separated by a ravine with steep scarps. The site of Vagnari is divided into two nearly equal halves by a shallow ravine (see Figure 14). In 2002, a cemetery (late 1^{st} to 4^{th} centuries A.D.) was discovered in the southern part of the site (Small and Small, 2007a).

The northern half of the settlement was occupied during the 4^{th} century B.C. and was then continuously occupied from the 1^{st} century A.D. until it began to decline in the 3^{rd} century A.D. (Small and Small, 2005). The cemetery ceased to be utilized in the 4^{th} century A.D. (Small and Small, 2005). New buildings were discovered in the southern part of the site and appear to have been utilized from the 4^{th} to 6^{th} centuries A.D. (Small and Small, 2005). After this time, the village was abandoned and a simple hut was constructed on top of the village remains (Small and Small, 2007a).

Magnetometer survey and excavations have revealed a large complex of buildings, some of which contained workshops. Three smithies (metalsmithing shops) have been excavated to date; two in the northern half of the site (1^{st} to 3^{rd}

centuries A.D.) and one in the southern half of the site (3rd to 6th centuries A.D.) (Small and Small, 2005). Six kilns have been excavated and range in date from the end of the 1st century B.C. to the early 4th century A.D. (Small and Small, 2005).

Ceramic wasters provide evidence of small scale pottery production at the site, which may have been intended for use within the village (Small and Small, 2005). Four Early Empire tiles bearing the stamp of the emperor or of Gratus, an imperial slave, have been found in and around the area of Vagnari (Small, 2003; Small et al., 2003). Vagnari seems to have been a center for iron-working and tile-making, and, in light of the stamped tiles, the center of an imperial estate as well (Small, 2003; Small, 2007; Small et al., 2003, Small and Small, 2007a). The 5,000 m^2 villa site at San Felice is now believed to be connected with Vagnari, perhaps as the home of the imperial administrator (Small and Small, 2005; Small and Small, 2007a). The land governed by the imperial estate at Vagnari is believed to have been quite large at roughly 3050 hectares (Small and Small, 2005).

In general, occupation of the Basentello River Valley during the Middle Empire (c. 70 to 300 A.D.) experienced an increase in the number of sites, which were distributed like the Early Empire sites with some intensification to the south-east of Gravina (Small, 1991). At this time, the northern part of the site of Vagnari was occupied and the cemetery was in use. During the Late Antique Period (c. 300 to 600 A.D.), which is at the end of the Vagnari cemetery usage and a period when the southern part of the site was occupied, there were a comparable number of sites located in areas similar to those used during previous periods (Small, 1991).

Small (1991) hypothesized that the sparse inhabitation of the area during the Roman period may have been due to the fact that grain farms would not have required a large residential population, as much of the labor could have been completed by migrant workers during plowing, sowing, and harvest seasons. Alternatively, the land around Silvium may have been forested during the Roman period (Small, 1991).

Life and Death in Roman Italy

Enamel hypoplasia defects can indicate individual stress experienced during childhood, when enamel deposition occurs. For the purposes of this research, a discussion of what life was like for Roman children living in rural environments like Vagnari would be useful. Much of what we know about early childhood health is derived from medical texts such as the *Gynaecology* of Soranus of Ephesos (early 2nd century A.D.) and the *Hygiene* of Galen of Pergamum (late 2nd century A.D.) in addition to historical texts such as the *Saturnalia* of Macrobius (early 5th century A.D.) (Green, 1951; Tempkin, 1956). These texts could be criticized for being prescriptive (rather than descriptive) and as being written for the literate socially elite (Prowse et al., 2008).

Although the Roman Empire did enjoy economic prosperity and growth as previously discussed, infant and childhood mortality was quite high and the average adult life expectancy was less than 35 years of age (Chamberlain, 1979; Garnsey, 1991; Harlow and Laurence, 2002; Temin, 2006). Roman parents could expect to lose at least one child (Harlow and Laurence, 2002).

Life during the Roman Republic and Empire was particularly difficult for infants and children. If a fetus was carried to term and survived the birthing process, the first difficulty would be whether the infant was accepted by the father (Casson, 1998; Harlow and Laurence, 2002). The father, who was the head of the Roman household and owner of all of its family members, could choose to commit infanticide (the killing of an infant) by either direct or, more often, indirect means (Casson, 1998; Harlow and Laurence, 2002). There were many reasons to consider infanticide including the health of the infant, sex of the infant (males were preferred), the number of children (heirs) already within the family, and the ability of the family to provide for a child (Casson, 1998; Garnsey, 1991; Saller and Kertzer, 1991). It seems that indirect infanticide by exposure (the abandonment of an infant) was practiced throughout social classes, though the poorer classes resorted to exposure more often (Casson, 1998; Garnsey, 1991). The fate of abandoned infants was not always that of death. Some may have been taken into households to live as slaves. For families of poor socio-economic status, an alternative to exposure would have been to sell the infant into slavery (Casson, 1998; Garnsey, 1991).

This uncertainty during the first few days of life can be reflected in Roman naming traditions. According to Macrobius (*Sat* 1.16.36), naming occurred on the *dies lustricus*, on the 8th day after birth for females and the 9th day for males (as cited in Casson, 1998; Garnsey, 1991; Harlow and Laurence, 2002). Until the *dies lustricus*, a child was considered to be in limbo and not fully human (Garnsey, 1991). Sometime during the following 30 days, the father would enter the child's name into the public register (Casson, 1998).

Other risks of infancy were related to nutrition. The ancient medical writers Soranus and Galen asserted that a mother's milk was best for her infant, although Soranus did urge the avoidance of colostrum (Harlow and Laurence, 2002). Stini (1985) also notes that colostrums, the first milk produced for the first few days after parturition, contains approximately three times the amount of protein in comparison to mature human milk. The avoidance of colostrum would have significantly reduced an infant's overall nutrition and diminished its chance of survival. According to Garnsey (1999), encouraging mothers to wait 20 days before breast feeding meant that infants were missing out on important antibodies in addition to a lowered level of milk production and increased risk of infection for the mothers.

At a somewhat later period, nutrition could be compromised by the process of weaning and often resulted in "weanling diarrhea" and increased morbidity (Garnsey, 1991). Early weaning was heavily criticized while Soranus and Galen preferred late weaning (Garnsey, 1991). The first dangerous period began around 3 months of age with the introduction of supplementary foods such as breads moistened with milk, honey, and wine, which may have been poor in nutritional value in comparison to breast milk (Garnsey, 1991, 1999). During the time period between 9 months and 2 years, feeding would have to become more reliant on food sources other than breast milk in order to keep up with the caloric demand of childhood growth rates (Garnsey, 1991). Ancient literary sources recommended foods such as soft cereals (i.e., wheat, spelt, etc.) or eggs for the later stages of the weaning process (e.g., Garnsey, 1999). Weaning is not considered to be complete until breast milk is completely replaced with supplementary foods, which could take as long as 2 to 3 years (Bradley, 1980; Garnsey, 1991).

Since weaning is a process rather than a punctuated event, the entire weaning period could be viewed as dangerous for Roman children. Infants also lose passive immunity obtained through maternal breast milk, so they are at greater risk of infection and disease (Katzenberg et al., 1996). In addition, infants and young children can become susceptible to malnutrition and undernutrition with the introduction of new food sources that are nutritionally incomplete and/or not prepared hygienically (Katzenberg et al., 1996; Moggi-Cecchi et al., 1994; Rodney, 1983). Children are also exposed to new pathogens in the environment, either through food-borne bacteria or from other sources (Garnsey, 1991).

Childhood was particularly short-lived for Roman children. According to the ancient writer Gaius, females were usually married at around 12 years of age while males married at about 14 years of age, thus effectively ending the period of childhood and marking the onset of adulthood (as cited by Casson, 1998; Harlow and Laurence, 2002).

Ancient literary sources do not contain much information concerning Roman childhood, and even less concerning the health of these children. The information that is available largely concerns those individuals of elite status within Roman society, which may not be applicable for rural populations such as Vagnari. This emphasizes the necessity of conducting bioarchaeological studies, such as the present study, to elucidate information about the quality of life for rural Roman populations like Vagnari.

Fig. 6: A historic glass slide photograph depicting the Appian Way and associated monuments near Rome, Italy (Keystone View Co. Studios, Meadville, PA., © Underwood and Underwood).

Fig. 7: Roman Coliseum (exterior). Rome, Italy. Photograph by Chrystal Lea Nause (© 2007).

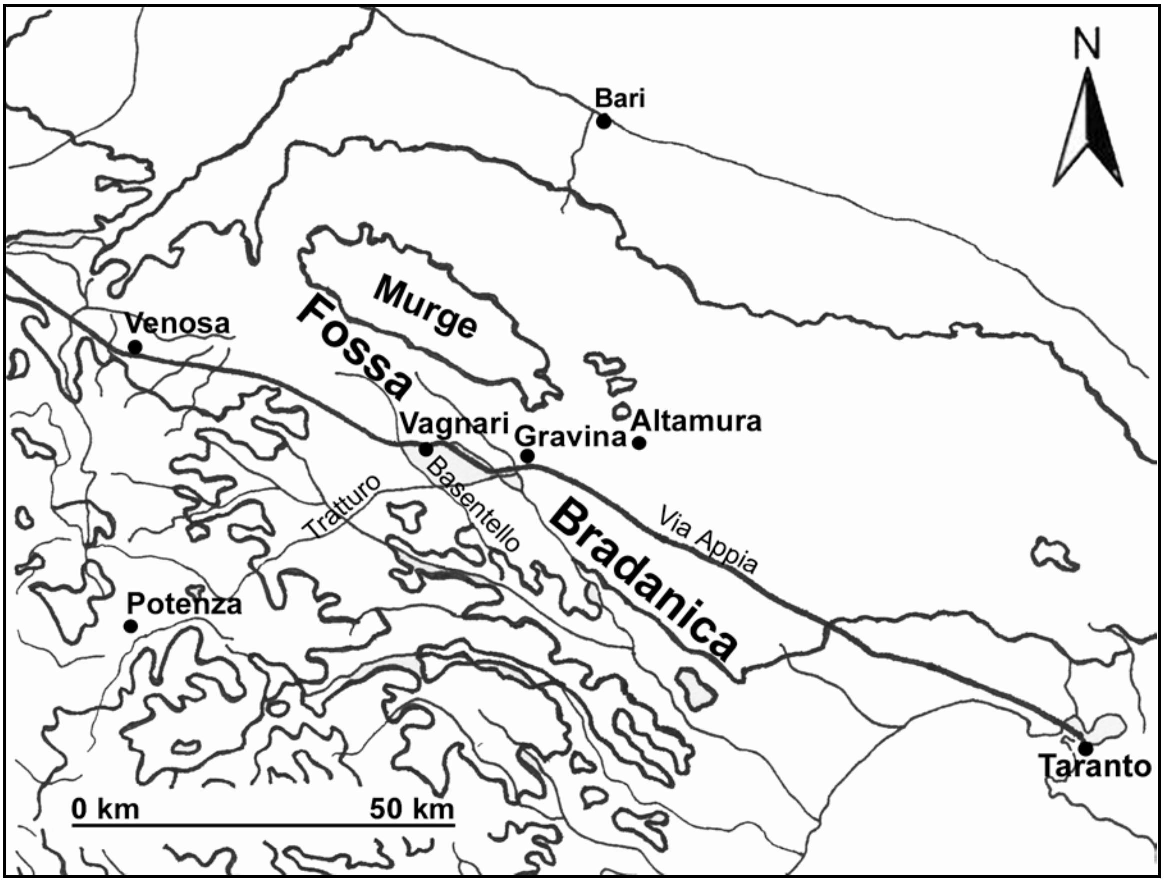

Fig. 8: The location of Vagnari. Adapted and redrawn by Chrystal Nause from Small and Small (2007b:124).

Fig. 9: The *Murge* in the background. At the junction of SP 230 and SP 138, near Spinazzola, Italy. Photograph by Chrystal Lea Nause (© 2008).

Fig. 10: A March 2003 NASA satellite image of Italy. The *Via Appia* is highlighted in white and connected Rome to Brindisi by way of Silvium, near modern day Gravina (marked with a white star). (**http://en.wikipedia.org/wiki/AppianWay**. 10/08/08).

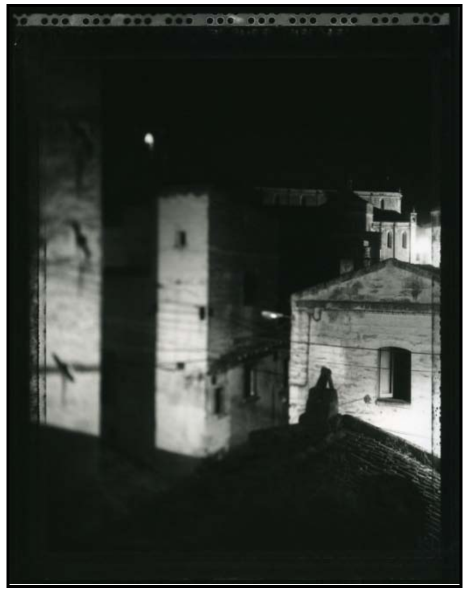

Fig. 11: Old City (*Cittá Vecchia*). Gravina in Puglia, Italy. Photograph by Chrystal Lea Nause (© 2007).

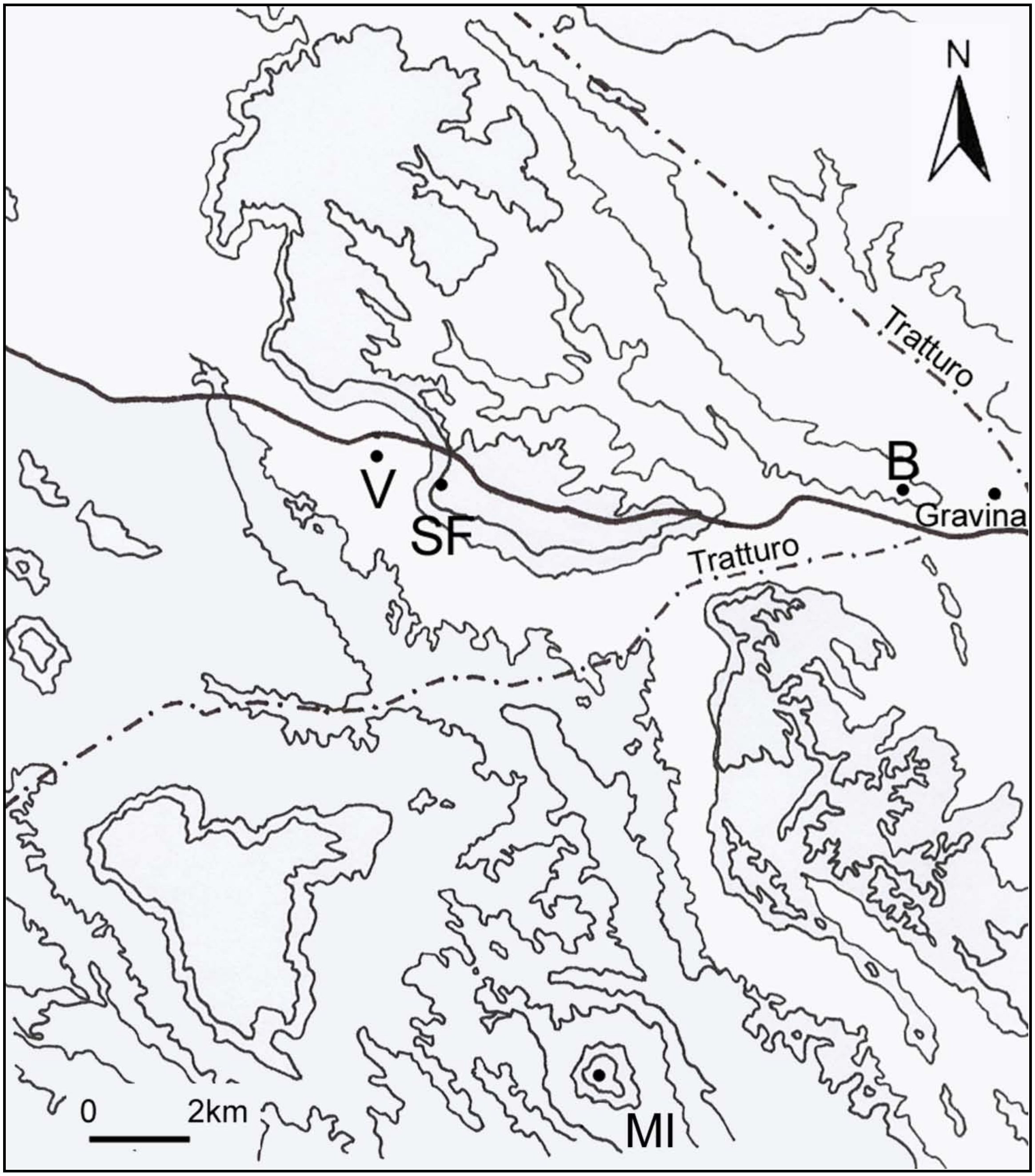

Fig. 12: Local sites of Botromagno (B), Monte Irsi (MI), San Felice (SF), and Vagnari (V). The *Via Appia* is indicated with a bold line. The dashed lines indicate *tratturi* for sheep herding. Map by A. and C. Small, adapted and redrawn by Chrystal Nause, from Ridgway (2002:127).

Fig. 13: San Felice from the site of Vagnari. Gravina in Puglia, Italy. Photograph by Chrystal Lea Nause (© 2008).

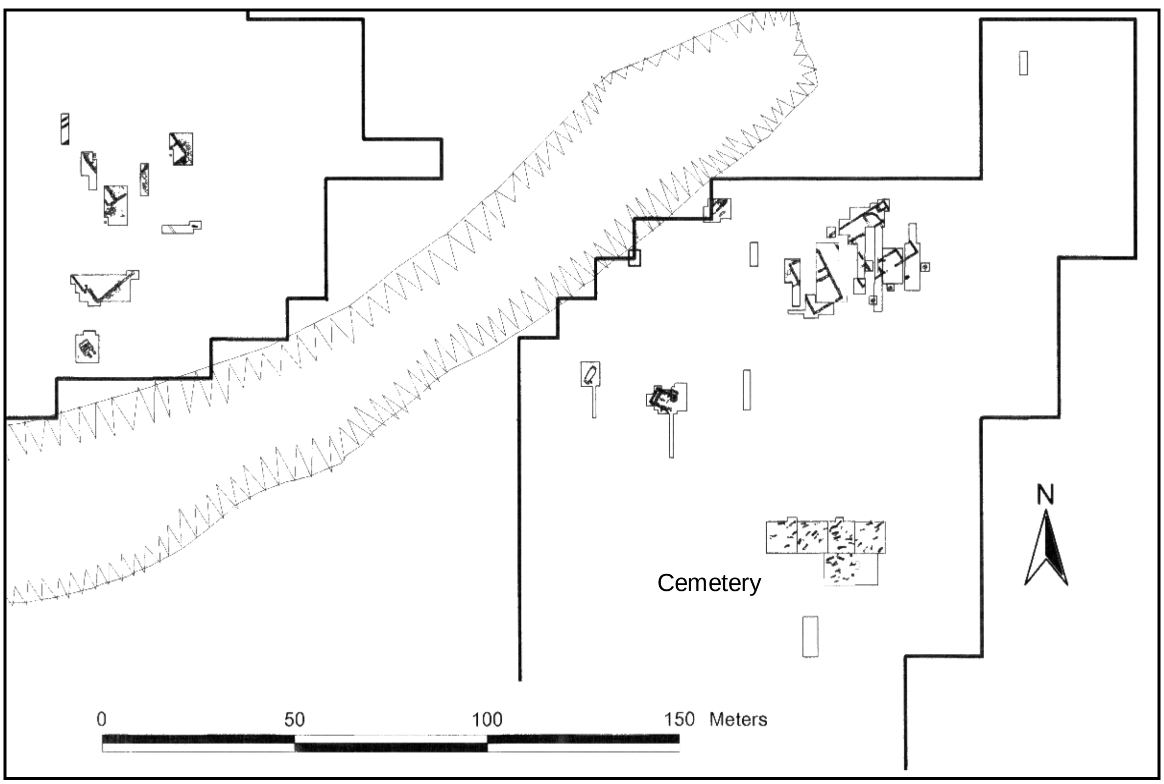

Fig. 14: Plan showing the location of test trenches and the cemetery at the site of Vagnari. Illustrated by Carola Small and Franco Taccogna.

CHAPTER 4

MATERIALS AND METHODS

Between 2002 and 2008, excavations in the cemetery at Vagnari have revealed a total of 69 burials (Prowse and Small, 2009) (see Figure 15). Most of these burials date from the late 1st to the 3rd century A.D., although some date to the 4th century (Small, 2007). Dating of the site and cemetery has largely relied on sequences of pottery artifacts and coins recovered from some of the burials (Small, 2007).

Stamped tiles found in and around the Vagnari site suggest that this settlement, the surrounding industrial zone, and the cemetery were part of an imperial estate (Small et al., 2003; Small and Small, 2005). It is hypothesized that the individuals buried in the cemetery represent the labor force for this rural estate (Prowse, 2007). Stable isotope evidence suggests that some individuals buried in the cemetery may have come from other parts of Italy and the Mediterranean, and mtDNA evidence demonstrates that none of these individuals were maternally related (Prowse et al., in press). This combined evidence suggests that a heterogeneous group, some of whom were not Italian by birth, lived, worked, and died at Vagnari (Prowse et al., in press).

With few exceptions, the tops of graves have been found approximately 50centimeters below the modern-day ground surface and have often been sheared off by modern agricultural plowing (Prowse and Small, 2009; Small, 2007). The Roman ground surface has also been damaged by modern agricultural activity (Small, 2007). Grave orientation tends to run in a northeast-southwest direction, although there is variation within the cemetery. In most instances, the cranium is to the northeast and the skeletons are typically in an extended position on their backs with the arms at their sides or across the body (over the chest or pelvis) (Prowse and Small, 2009; Small, 2007).

The most common type of burial style in the cemetery is the "*a cappuccina*" grave, which is the most common type of grave used in Italy from this time period (Prowse and Small, 2009; Small, 2007). In this type of burial, the corpse was placed into a shallow pit that was backfilled with soil. *Tegulae (*large flat terracotta roofing tiles with lipped sides*)* were stacked over the body in an inverted "V", with *imbrices* (curved roofing tiles) placed along the apex of the adjoining *tegulae* (Small, 2007) (see Figure 16).

On occasion, an *imbrex* tile was placed perpendicular to the main axis of the burial at the end of the grave to serve as a headrest for the individual's cranium (Prowse and Small, 2009; Small, 2007). The tiles do not have funerary inscriptions but occasionally display deep fingerprints and concentric, inverted u-shapes that resemble rainbow-like forms.

Several variations of this burial type exist. One type involves a layer of horizontal *tegulae* laid below the skeleton with the tile flanges oriented upwards or downwards. Another type of burial, referred to as a "mortar" burial in this study, is an *a cappuccina* burial (any variation) exteriorly reinforced with small stones set in mortar (see Figure 17).

A number of burials were of the “libation” or “funnel” type; another common type of burial in which the deceased was interred in a pit and then covered with horizontally placed *tegulae* with a vertically projecting funnel (see Figure 18). The funnel feature is generally made of two *imbrices* although single tubular tiles have been found at Vagnari. Although all of the tops of these libation funnels have been damaged since the time of their installation, Small (2007) hypothesized that the funnels would have projected about the ground surface during the Roman period in order to permit the offering of libations in honor of the dead.

Several burial types are less commonly found at the site of Vagnari. Simple “pit” or “soil” depositions are those in which the individual was placed in a shallow pit without a tile or stone mortar covering. In two of these (both infant burials), the presence of a wooden coffin was inferred by the presence and arrangement of large iron nails with traces of organic material (see Figure 19), and in another infant burial, the body was placed on top of a *tegula* that had no tile cover and was labeled as “other” tomb type in this study (Prowse and Small, 2009).

Only two “cremation” burials have been uncovered to-date at Vagnari. Cremation burials at this site involved burning the corpse *in situ* and reducing it to ashes and small bone fragments through intense heat (see Figure 20). Careful excavation has revealed evidence of cremated bone and tooth fragments. According to Small and colleagues (2007), inhumation began to replace cremation as the preferred method of body deposition in the late 1st century A.D.

In six cases, the aforementioned burial types would be *disturbed,* meaning that the burial's original integrity had been compromised as a result of later activity. No grave markers have been found at this cemetery, so it is probable that later graves were dug without knowing the exact location of earlier graves and inadvertently disturbed these previous burials (Small, 2007). Other rural cemeteries (e.g., via di Grottaperfetta near Rome and Nave in Lombardy) have reported similar grave disturbances (Pagliardi and Cecchini, 2004; Passi Pitcher, 1987, both cited in Small, 2007:133).

These burials usually contained modest grave goods generally consisting of pottery vessels (sometimes containing bent iron nails), lamps, glass vessels, bronze coins, and items of personal adornment (Small, 2007) (see Figure 21). These goods were often placed near the feet of the deceased, although items of dress were usually located where they would have been worn in life (i.e., rings would be found near a hand) (Small, 2007).

It should be noted that Small and colleagues (2007:138) have argued that the presence of certain pottery wares, such as African red slip vessels, suggests that "…the community at Vagnari was living at a reasonable level of subsistence, in spite of the[ir] physically demanding lifestyle…". Small (2007) has interpreted the iron nails as everyday construction materials that were bent for magical purposes, likely to prevent the spirit of the dead from returning to the living world (see Figure 21).

Although the tiles and grave goods often remain *in situ*, they are frequently found broken. It is hypothesized that these items were intentionally damaged at the time of burial and may be linked to ritual activities in which the objects were "ritually killed in order to separate them from the world of the living, and prevent their reuse" (Small, 2007:133). However, some of the pots found in burials are complete, yet fragmentary, suggesting that they were damaged sometime after interment.

Table 2 shows the numbers of individuals according to burial type. No cremation burials were included in this analysis.

The Skeletal Sample

This study examined 525 permanent and 131 deciduous teeth of 18 subadults, 29 adults, and one individual of unknown age (total = 48) excavated between 2002 and 2007. The Vagnari skeletal sample is currently housed in the offices of the Superintendency of Gravina in Puglia, under the direction of Dottoressa Pina Canosa. Age estimates and dental assessments were made for each of these skeletons by Prowse (2007). Adult age was estimated using the auricular surface morphology, pubic symphysis morphology, and cranial suture closure methods (after Buikstra and Ubelaker, 1994). Subadult age was determined using dental crown formation and eruption as well as long bone length (Ubelaker, 1989). Sex determination relied on pelvic and cranial morphological features (after Bass, 1987). Long bone measurements were used to confirm assessments of sex (after Bass, 1987).

The estimated age at death of individuals in the sample ranged from birth to 51 years, with eight individuals being classified as “adult” and one as an unknown age (Appendix A). This study examined the remains of 15 females, 10 males, and 23 individuals of unknown sex (18 subadults and 5 adults). Abscesses, ante-mortem tooth loss, tooth wear (attrition), dental caries (cavities), and calculus were also recorded for each individual (Prowse, 2007).

Hypoplasia Data Collection

All aspects of this investigation were non-destructive. A total of 656 teeth, an average of 14 teeth per individual, were macroscopically examined for hypoplastic defects (following the standards of Buikstra and Ubelaker, 1994; Kreshover, 1960; Massler et al., 1941; Sarnat and Schour, 1941) during the months of June through August 2008.

Data were collected on the presence or absence of hypoplastic defects (nominal data collection method) from all teeth available for each individual examined. Enamel hypoplasias were marked as either “present” or “absent” for each tooth in order to determine frequencies per individual and per tooth. If an EH was present, the type of defect was noted (linear horizontal grooves, linear vertical grooves, linear horizontal pits, nonlinear arrays of pits, and single pits) (type data collection method). The hypoplasia appearance was ranked (ordinal data collection method) in order to determine the severity of each enamel defect (after Hoover et al., 2005). The position of each EH defect was measured using digital sliding calipers accurate within 1/100 of a millimeter to assess a chronological age at insult.

Casts of hypoplastic teeth were made if the total number of EH or measurement of a hypoplastic defect was difficult to determine while in the field. Coltene President Putty was used for the primary impression and Coltene President Light Body was used to capture the fine detail of the labial surface of the tooth crown. These molds were then used to make highly detailed positive casts using Dentstone KD (manufactured by BPB Formula) at Southern Illinois University Carbondale (see Figure 5). The casts were evaluated with a magnifying lens and direct light source to confirm the number and/or measurement of any hypoplastic defects present on the labial surface of the tooth.

Teeth were excluded from this study if they were not observable as a result of more than one-third occlusal wear, labial attrition, and/or carious lesions affecting the labial surface. In addition, teeth were excluded from the study if the defects were not measurable due to carious lesions or taphonomic damage along the CEJ.

Nominal Data Collection Method

In order for an enamel defect to be considered as “present”, at least one of the following criteria must be met in order to ensure a systemic origin of the defect (after Corruccini et al., 2005):

(1) Palpable on both antimeres at similar levels (Corruccini and Townsend, 2003; Goodman and Rose, 1990, 1991; Larsen, 1997)

(2) Also observed on another tooth that was developing during the same time period

(3) Present on both the lingual and labial surfaces of the tooth (defect circumscribes the tooth)

The total number of hypoplastic events per tooth was recorded for each tooth marked “defect present” according to Buikstra and Ubelaker (1994).

Type Data Collection Method

The standards created by Buikstra and Ubelaker (1994:56) were utilized to determine the type of hypoplastic defect, if present: 1) linear horizontal grooves, 2) linear vertical grooves, 3) linear horizontal pits, 4) nonlinear arrays of pits, and 5) single pits.

Ordinal Ranked Data Collection Method

The hypoplasia appearance ranking method (ordinal level) developed by Hoover and colleagues (2005) was used in order to determine the severity of each observed enamel defect. This hypoplasia ordinal ranking scale was modified from an earlier scale by Hoover (2001). The ordinal ranking developed by Hoover et al. (2005) was modified in the current study in order to follow a sequential ordinal ranking ranging between 0 and 3 (instead of a score of 0, 1, 2, or 4) (see Table 3).

Defect Position Measurement Method

The position of each labial surface EH defect was measured with Mitutoyo Absolute Digimatic metric digital sliding calipers, accurate within 1/100 mm, at the most occlusal portion of the defect to the CEJ on each affected tooth following the standards outlined by Buikstra and Ubelaker (1994).

Chronological Age-at-Insult Conversion Method

Age-specific occurrence of EH's were graphed to indicate the distribution of individual hypoplasia events according to the calcification scale adapted by Goodman et al. (1980) from Swärdstedt (1966) and Massler et al. (1941), a developmental scale based on Caucasians from the United States. Corruccini et al. (1985) suggested that calcification scales may be developmentally accelerated in comparison to malnourished populations. To maintain comparability with other studies, the scale was not adjusted for possible nutritional or ancestral differences in calcification. The Goodman et al. (1980) calcification scale does not include third molars; therefore, hypoplastic third molars were excluded from this analysis.

Data Analysis

Intrasite analysis was conducted to determine if hypoplastic defect trends could be linked to sex, age, dental arcade, tooth types, and tomb types. Goodman and Armelagos (1985) suggested that anterior teeth may be more susceptible to hypoplastic defects than the posterior dentition. A later study by Goodman and Rose (1990) recommended that the permanent maxillary central incisors and mandibular canines be used for EH studies (see page 10). To explore these possibilities, reanalysis of the data was performed using only the anterior dentition and the permanent maxillary central incisors and mandibular canines.

The results were then compared to EH data from samples with similar archaeological and historical contexts to determine the relative stress level of the sample (i.e., Casalecchio di Reno, Isola Sacra, Lucus Feroniae, Mendes, Quadrella, Ravenna, Rimini, Urbino, and Vallerano). The comparison of Vagnari with other contemporaneous samples serves to indicate the overall level of stress experienced by these individuals within a broader context of health in Roman Italy. Although these individuals were living in a relatively similar geographical, political, and cultural Roman landscape, local political and economic circumstances have the ability to mitigate or exacerbate stress levels. In this way, this research integrates bioanthropological, archaeological, historical, and geographical information. Furthermore, the relationship between stress, lifestyle, and overall health can be discussed.

Statistical Analysis

The statistical package used to analyze the data presented in the following chapters was SPSS 16.0 for Windows (SPSS, 2007). Charts were produced using Microsoft Office Word (Microsoft Corporation, 2003). Graphs were produced using Microsoft Office Excel (Microsoft Corporation, 2003).

TABLE 2: Numbers of Individuals According to Burial Type

Burial Type	**Number**
A cappuccina	27
Mortar	3
Libation	6
Pit	5
Other	1
Disturbed	6
Total	**48**

TABLE 3: Modified Hypoplasia Ordinal Ranking Scale (after Hoover et al., 2005:756)

Score	**Classification**	**Appearance**
0	absent	no hypoplasias present
1	mild	one linear episode
2	average	one linear episode and/or pitting on up to 1/3 of the crown
3	severe	multiple linear episodes and/or deep episodes with clearly exposed dentine and/or pitting on over 1/3 of the crown

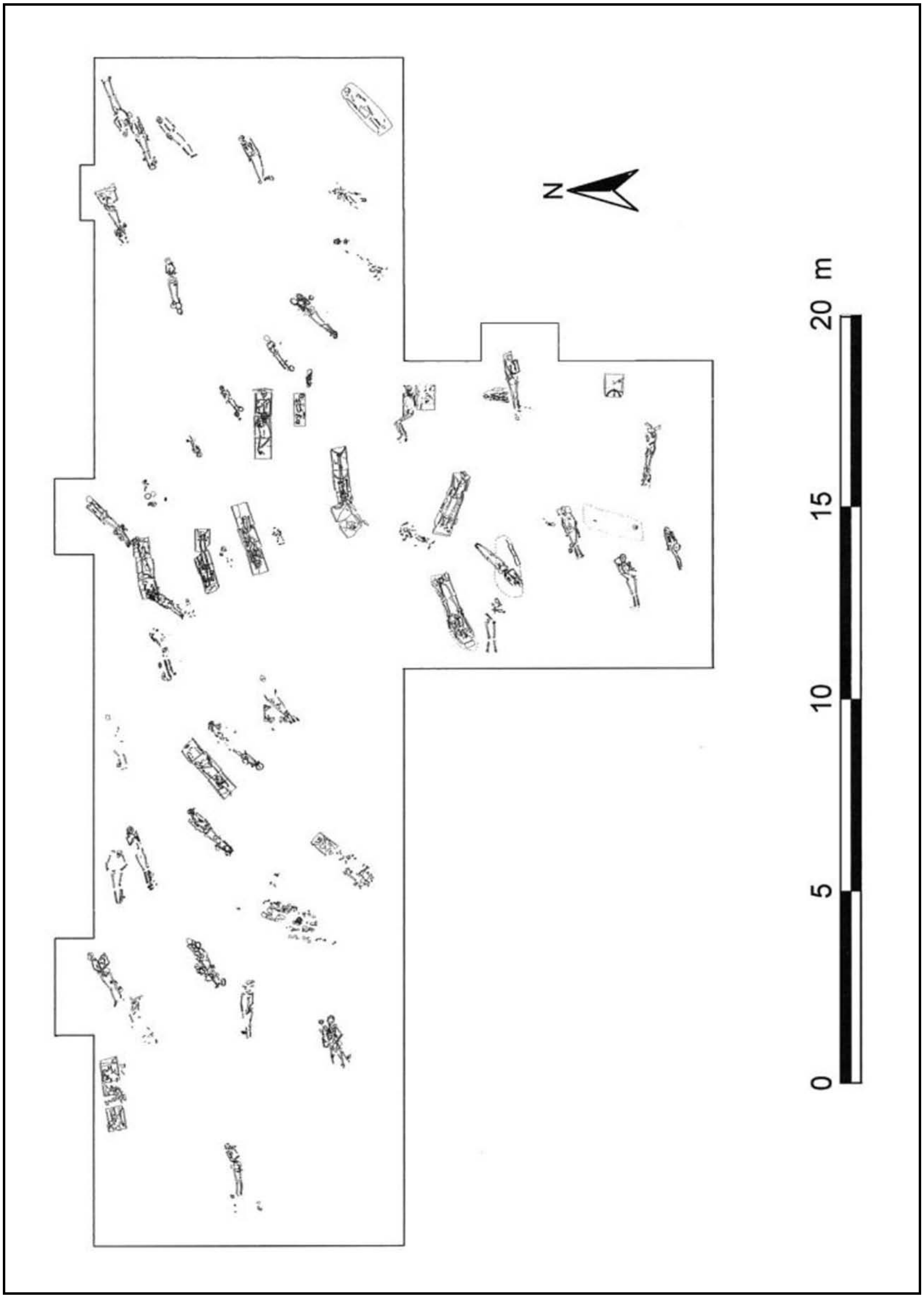

Fig. 15: Plan of cemetery (2002-2008), illustrating the location of trenches excavated as of 2008 (Prowse and Small, 2009:2).

Fig. 16: An "*a cappuccina"* burial (photograph courtesy of Tracy Prowse).

Fig. 17: A "mortar" burial (photograph courtesy of Tracy Prowse).

Fig. 18: A “libation” burial with funnel tube near the North arrow (photograph courtesy of Tracy Prowse).

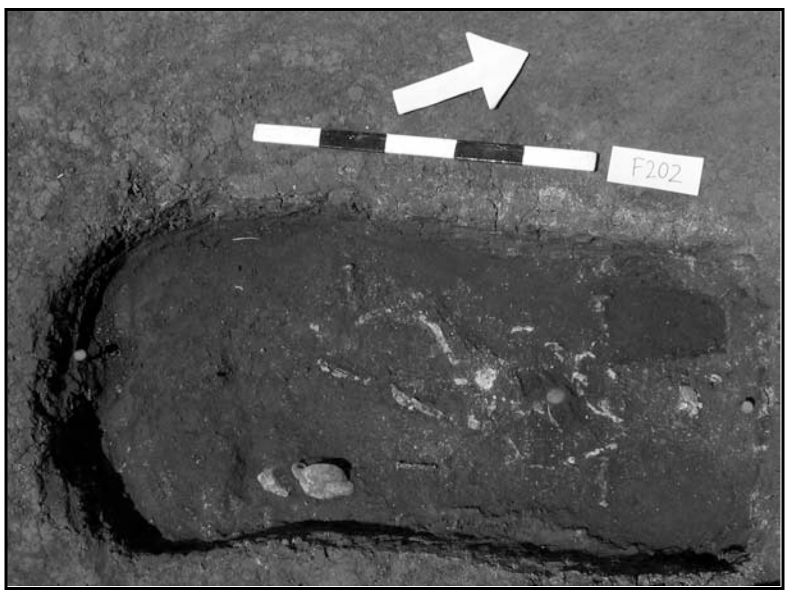

Fig. 19: An infant (F202b) buried in a coffin, which is classified as a “pit or “soil” burial (photograph courtesy of Tracy Prowse).

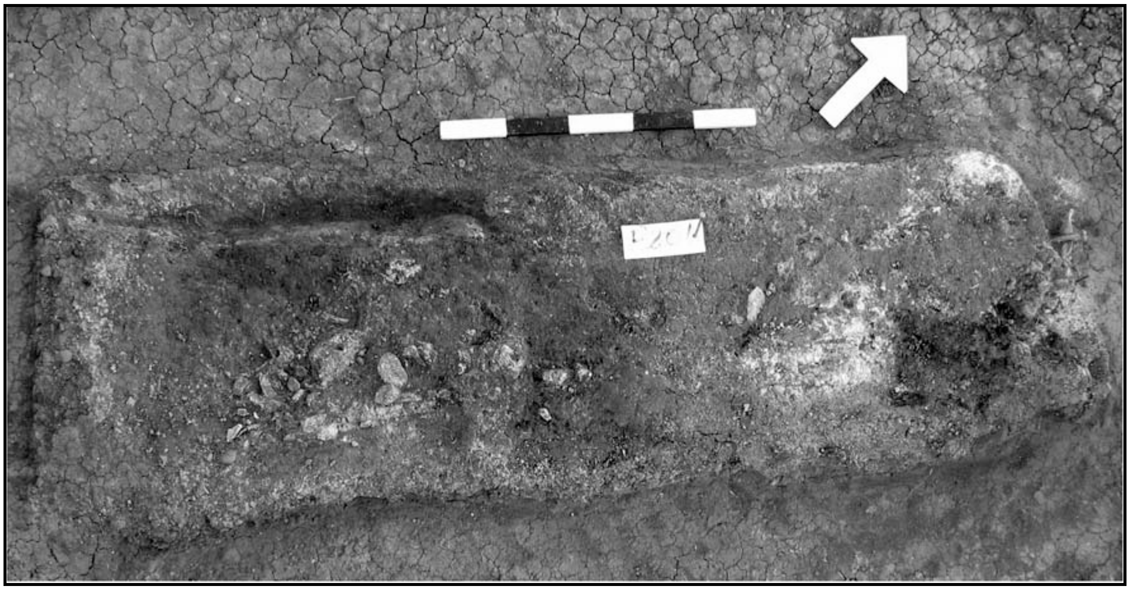

Fig. 20: A “cremation” burial (photograph courtesy of Tracy Prowse).

Fig. 21: Image of a bent iron nail inside of a pot (photograph courtesy of Tracy Prowse).

CHAPTER 5

RESULTS

This study analyzed a total of 48 individuals with 656 teeth, (131 – deciduous; 525 – permanent). The remains of 15 females, 10 males, and 23 individuals of unknown sex (18 subadults and 5 adults) were examined. The estimated age at death of these individuals ranges from birth to 51 years, with 18 subadults (<15 yrs), 29 adults, and 1 adult of unknown age (Appendix A). Of the 525 permanent teeth analyzed, 256 were maxillary and 269 were mandibular teeth.

Of the 48 individuals analyzed, 31 (64.6%) were found to have at least one tooth with an EH, identified according to the criteria outlined by Corruccini et al. (2005). When only the permanent anterior dentition was analyzed, 27 (56.1%) were found to have at least one tooth with an EH, according to the suggestion by Goodman and Armelagos (1985). This frequency diminishes to 21 individuals of the 48 analyzed (43.3%) when only the maxillary central incisors and mandibular canines were analyzed, according to the standards proposed by Goodman and Rose (1990). Only LEH defects were observed in the Vagnari sample. All of the teeth affected were permanent teeth; the deciduous dentition was not affected. Of the 525 permanent teeth analyzed, 280 of the teeth (53.3%) were found to have at least one hypoplastic defect. A total of 619 hypoplastic defects were observed (see Table 4). Of the 212 permanent anterior teeth analyzed, 119 of the teeth (56.1%) were found to have at least one hypoplastic defect. A total of 365 hypoplastic defects were observed (see Table 5). Of the 97 permanent maxillary central incisors and mandibular canines analyzed, 42 of the teeth (43.3%) were found to have at least one hypoplastic defect. A total of 144 hypoplastic defects were observed (see Table 6).

LEH by Sex

Of the 525 permanent teeth analyzed, individuals of unknown sex contributed 112, males contributed 166, and females contributed 247. More teeth were observed in females (47.0%), while the least amount of teeth were observed in individuals of unknown sex (21.3%) (see Table 7).

Of those teeth observed, females had a slightly higher percentage of teeth affected by EH's (54.7%). Individuals of unknown sex showed a slightly lower percentage of affected teeth (51.8%) (see Figure 22). However, those individuals of unknown sex had a slightly higher average number of defects per tooth (N = 1.5) than did males or females (N = 1.1 in each sex) (see Figure 23).

In order to take into account the number of observable and measurable teeth, individual averages were calculated for the "Number of Permanent Teeth with Defects", the "Total Number of Hypoplastic Defects", and the "Severity Ranking of Defects" (ranked 0 to 3).

To determine if there is a significant difference between the sexes, individuals of unknown sex were excluded from analysis. The data for "Average Number of Permanent Teeth with Defects" and "Average Severity Ranking of Defects" are normally distributed (Shapiro-Wilk, p = .230 and p = .123, respectively). The data for "Average Total Number of Hypoplastic Defects" are not normally distributed (Shapiro-Wilk, p = .028). To determine if there is a significant difference between the sexes in the "Average Number of Permanent Teeth with Defects", the data were subjected to an Independent Samples t-test (p = .924) and a Chi-square test (p = .449) and the differences are not statistically significant. Similarly, the "Average Severity of Defects" is also not statistically significant between the sexes, indicated by an Independent Samples t-test (p = .541) and a Chi-square test (p = .447). Finally, the "Average Total Number of Defects" between the sexes is not statistically significant, according to a Mann-Whitney U test (p = .488). The summary of results is shown in Table 8.

The data were analyzed using the permanent anterior dentition only, following the suggestion by Goodman and Armelagos (1985). The data for all variables are not normally distributed (Shapiro-Wilk, p = .000 for all variables). To determine if there is a significant difference between the sexes in the "Average Number of Permanent Teeth with Defects", "Average Total Number of Defects", and "Average Severity of Defects", the data were subjected to a Mann-Whitney U test (p = .285, .239, and .238, respectively) and the differences are not statistically significant. The summary of results is shown in Table 9.

The data were analyzed using the permanent maxillary central incisors and mandibular canines only, following the method outlined by Goodman and Rose (1990). The data for all variables are not normally distributed (Shapiro-Wilk, p = .000 for all variables). To determine if there is a significant difference between the sexes in the “Average Number of Permanent Teeth with Defects”, “Average Total Number of Defects”, and “Average Severity of Defects”, the data were subjected to a Mann-Whitney U test (p = .345, .334, and .218, respectively) and the differences are not statistically significant. The summary of results is shown in Table 10.

LEH by Age Category

Of the 525 permanent teeth analyzed, individuals 0-15 years of age (subadult) contributed 59, 16-30 years contributed 177, 31-45 years contributed 78, 46+ years contributed 114, and those categorized as “adult” contributed 97 (see Table 11). Among the subadults (aged 0-15 years), 106 EH defects were identified on a total of 59 observable teeth, averaging 1.8 defects per tooth. Adults contributed 466 permanent teeth to the sample, 250 were found to have at least one EH. A total of 513 defects were identified among observable teeth, averaging 1.1 defects per tooth, which is a lower average than the subadult category.

More teeth were observed in the 16-30 years category (33.7%), while the 0-15 years category (subadult) had the fewest teeth (11.2%). Individuals in the 31-45 years category had a higher proportion of teeth affected with EH’s (59.0%), but in all age categories more than 50% of the observable teeth displayed one or more hypoplastic defect. The least affected group was the “Adult” category (50.5%) (see Figure 24). The highest average number of defects observed per tooth by age category was the 0-15 years (subadult) group with 1.8 defects per tooth. The lowest average was observed in both the 46+ and “Adult” age categories with 0.9 defects per tooth (see Figure 25).

The highest “Average Severity Ranking of Defects” observed by age category was the 31-45 years group with an average score of 1.5. The lowest average was observed in the 0-15 years group (subadult) age categories with 0.3 (see Table 12).

In order to determine if there is a significant difference between age categories, individuals of unknown age (“Adult”) were excluded from analysis. “Average Number of Permanent Teeth with Defects”, “Average Total Number of Hypoplastic Defects”, and “Average Severity Ranking of Defects” data are not normally distributed (Shapiro-Wilk, p = .000 for each variable). For all three variables, Kruskal-Wallis tests revealed that there are significant differences between the age categories (p-values ranging from .001 to .002, see Table13).

The data were then collapsed into subadult (0-15 years) and adult (16+ years) categories. These data are normally distributed and an analysis was run (Chi-square, p = .117) comparing the subadult and adult categories, and is not statistically significant. There is no statistically significant difference between the two age groups for any of the three variables. The summary of results is shown in Table 13.

LEH by Dental Arcade

Of the total of 525 permanent teeth, 256 maxillary (48.8%) and 269 mandibular (51.2%) were observed. Maxillary permanent teeth were more frequently affected (56.6%) than mandibular permanent teeth (50.2%) (see Figure 26). In addition, more defects in total were observed in the maxillary dentition (N=347) in comparison to the mandibular dentition (N=272). The average number of defects for maxillary teeth was 1.4 defects per tooth, while the average for mandibular teeth was 1.0 (see Table 14).

“Average Number of Permanent Teeth with Defects” and “Average Total Number of Hypoplastic Defects” are not normally distributed (Shapiro-Wilk, $p = .000$ for both variables). Mann-Whitney U tests revealed that there are no significant differences between the dental arcades (p-values of .186 and .161, respectively). “Average Severity Ranking of Defects” data are normally distributed (Shapiro-Wilk, $p = .146$). Independent Samples t-tests and Chi-square tests revealed that there no are significant differences between the age categories ($p = .084$ and .399, respectively) (see Table15).

LEH by Tooth Type

The total number of deciduous and permanent teeth observed by tooth type (incisor, canine, premolar, molar) are presented in Table 16.

Of the 525 permanent teeth, 139 incisors, 73 canines, 144 premolars, and 169 molars were observed. Permanent molars were the most frequently observed type of tooth (32.2%), while permanent canines were the least frequently observed tooth type (13.9%), which could be expected because there are 12 molars but only 4 canines in the permanent dentition (see Table 17). Of the permanent teeth observed, canines were more frequently affected (64.4%) than other tooth types, while molars were the least affected tooth type (46.2%) (see Figure 27 and Table 17). Canines showed a slightly higher average number of defects per tooth type (2.0 per tooth). Molars had the lowest average number of defects at 0.6 defects per tooth (see Table 17).

LEH by Tomb Type

Of the 48 individuals analyzed, 27 were discovered in *a cappuccina* burials, 6 in disturbed contexts, 6 in libation burials, 3 in mortar burials, 1 in "other" (F224 was an infant buried on top of a tegula but had no tile covering), and 5 in soil burials.

A higher percentage of permanent teeth were observed in those individuals buried in *a cappuccina* style burials (59.0%). The lowest percentage of permanent teeth was observed from individuals found in soil burials (0.6%). No permanent teeth were observed in individuals classified as "other" types of burials. Of the permanent dentition that was observed, a higher percentage of teeth were affected among individuals from mortar burials (70.2%). The lowest percentage of affected teeth was observed among those with disturbed burial contexts (46.5%) (see Table 18). Individuals in the soil burials were not affected by EH's (see Figure 28). Of those individuals affected by LEH's, the average number of defects per tooth was highest in those individuals in mortar burials (N = 1.4). The lowest average was found among those in disturbed burial contexts (N = 0.8) (see Figure 29).

"Average Number of Permanent Teeth with Defects", "Average Total Number of Hypoplastic Defects", and "Average Severity Ranking of Defects" data are not normally distributed (Shapiro-Wilk, p = .000 for each variable). There is no statistically significant difference in the prevalence or severity of LEH between the different tomb types, although the differences are approaching significance (Kruskal-Wallis test). The summary of results is shown in Table 19.

LEH Age-Specific Occurrence

An age distribution of individual hypoplastic events in Vagnari individuals was obtained by measuring from the most occlusal portion of each labial surface EH defect to the CEJ on each affected tooth (according to Buikstra and Ubelaker, 1994). An age for each hypoplastic defect was calculated according to a crown calcification scale (Goodman et al., 1980). Third molar hypoplastic defects were excluded for aforementioned reasons (according to Goodman et al., 1980). The histogram for 591 individual hypoplastic events is given in Figure 30**.** Hypoplasia occurrence follows a quasi-normal distribution peaking at 2.75 years.

Tooth type crowns (i.e., the right and left maxillary central incisor) form simultaneously, therefore each tooth type should represent a stress incident twice if both teeth are present. To counteract error that may have been produced by counting hypoplastic incidents twice the Vagnari EH Age at Occurrence histogram (see Figure 30) was adjusted by utilizing only the measurements from the right side of the dentition to reduce error. If a right tooth was not present, then the same tooth type was supplemented from the left side of the dentition. The histogram for 401 individual hypoplastic events is given in Figure 31**.** Hypoplasia occurrence follows a bimodal distribution peaking at 2.75 and 4.75 years, with hypoplasia occurrence reducing after 5.25 years.

Analysis of the Vagnari data reveals a number of noteworthy findings. First, only linear enamel defects on the permanent dentition were observed. Second, the differences between males and females are not statistically significant. Third, the differences between age categories are statistically significant, but the differences between subadults (0-15 years) and adults (16+ years) are not statistically significant. Fourth, the maxillary dentition is more frequently affected (maxillary – 56.6%; mandibular – 50.2%) and also average a higher number of defects per tooth (maxillary – 1.4; mandibular – 1.0) than did the mandibular dentition. Fifth, the canine teeth are more frequently affected (canine – 64.4%; molars – 46.2%) and also average a higher number of defects per tooth (canine – 2.0; molar – 0.6) than did the molar teeth, but these differences are not statistically significant. Sixth, EH occurrence follows a normal distribution peaking at 2.75 years.

TABLE 4: Number of Teeth Observed and Number of Teeth Affected by Linear Enamel Hypoplasias in the Deciduous and Permanent Dentition

	# of teeth observed	# of teeth affected (1 or more defects)	% affected	Total # of defects
Deciduous	131	0	0	0
Permanent	525	280	53.3	619
Total	656	280	42.7	619

TABLE 5: Number of Teeth Observed and Number of Teeth Affected by Linear Enamel Hypoplasias in the Permanent Anterior Dentition

	# teeth observed	% observed	# teeth affected	% affected	# defects	Average # defects/ tooth
Incisors	139	65.6	72	51.8	216	1.6
Canines	73	34.4	47	64.4	149	2.0
Total	212	100.0	119	56.1	365	1.8

TABLE 6: Number of Teeth Observed and Number of Teeth Affected by Linear Enamel Hypoplasias in the Permanent Maxillary Central Incisors and Mandibular Canines

	# teeth observed	% observed	# teeth affected	% affected	# defects	Average # defects/ tooth
Maxillary Central Incisors	48	49.5	19	39.6	71	1.5
Mandibular Canines	49	50.5	23	46.9	73	1.5
Total	97	100.0	42	43.3	144	1.5

TABLE 7: Prevalence of LEH in Permanent Teeth by Sex

Sex Category	# teeth observed	% observed	# teeth affected	% affected	# defects	Average # defects/ tooth
Male	166	31.6	87	52.4	183	1.1
Female	247	47.0	135	54.7	273	1.1
Unknown	112	21.3	58	51.8	163	1.5
Total	525	100.0	280	53.3	619	1.2

TABLE 8: LEH Statistical Analysis by Sex

Variable	Shapiro-Wilk	Mean	Skew-ness	Kur-tosis	Ind. Samples t-test	Chi-square	Mann-Whitney U
Avg. # of Teeth with EH Defects	.948 (p = .230)	.3804	.279	-0.542	.096 (p = .924)	20.139 (p = .449)	-
Avg. Total # of EH Defects	.908 (p = .028)	.8204	.843	.098	-	-	62.500 (p = .488)
Avg. Severity of EH Defects	.937 (p = .123)	1.0432	.257	-1.099	.621 (p = .541)	22.222 (p = .447)	-

TABLE 9: LEH Statistical Analysis in the Permanent Anterior Dentition by Sex

Variable	Shapiro-Wilk	Mean	Skew-ness	Kur-tosis	Ind. Samples t-test	Chi-square	Mann-Whitney U
Avg. # of Teeth with EH Defects	.789 (p = .000)	.2792	.712	-1.126	-	-	56.000 (p = .285)
Avg. Total # of EH Defects	.659 (p = .000)	.9021	2.924	11.689	-	-	54.000 (p = .239)
Avg. Severity of EH Defects	.790 (p = .000)	.9521	.701	-1.139	-	-	53.000 (p = .238)

TABLE 10: LEH Statistical Analysis in the Permanent Maxillary Central Incisors and Mandibular Canines by Sex

Variable	Shapiro-Wilk	Mean	Skew-ness	Kur-tosis	Ind. Samples t-test	Chi-square	Mann-Whitney U
Avg. # of Teeth with EH Defects	.736 (p = .000)	.2792	.964	-0.580	-	-	58.500 (p = .345)
Avg. Total # of EH Defects	.623 (p = .000)	1.0458	2.920	11.350	-	-	58.000 (p = .334)
Avg. Severity of EH Defects	.790 (p = .000)	.9521	.701	-1.139	-	-	53.000 (p = .218)

TABLE 11: Prevalence of LEH in Permanent Teeth by Age Category

Age Category	# teeth observed	% observed	# teeth affected	% affected	# defects	Average # defects/ tooth
0-15 yrs	59	11.2	30	50.8	106	1.8
16-30 yrs	177	33.7	94	53.1	234	1.3
31-45 yrs	78	14.9	46	59.0	82	1.1
46+ yrs	114	21.7	61	53.5	107	0.9
Adult	97	18.5	49	50.5	90	0.9
Total	525	100.0	280	53.3	619	1.2

TABLE 12: Severity of LEH in Permanent Teeth by Age Category

Age Category	Total # of Individuals	Total Severity Ranking	Average Severity Ranking/Tooth
0-15 yrs	18	5.8	0.3
16-30 yrs	10	10.7	1.1
31-45 yrs	4	6.1	1.5
46+ yrs	7	7.3	1.0
Adult	9	8.9	1.0
Total	48	7.7	1.0

TABLE 13: LEH Statistical Analysis by Age Category

Variable	Shapiro-Wilk	Mean	Skew-ness	Kurtosis	Chi-square	ANOVA	Kruskal-Wallis
Avg. # of Teeth with EH Defects	.837 (p = .000)	.264	.745	-0.627	-	-	17.083 (p = .001)
Avg. Total # of EH Defects	.704 (p = .000)	.683	2.544	8.670	-	-	15.883 (p = .001)
Avg. Severity of EH Defects	.853 (p = .000)	.765	.598	-0.936	-	-	14.663 (p = .002)

TABLE 14: Prevalence of LEH in Permanent Teeth by Dental Arcade

Dental Arcade	# teeth observed	% observed	# teeth affected	% affected	# defects	Average # defects/ tooth
Maxilla	256	48.8	145	56.6	347	1.4
Mandible	269	51.2	135	50.2	272	1.0
Total	525	100.0	280	53.3	619	1.2

TABLE 15: LEH Statistical Analysis by Dental Arcade

Variable	Shapiro-Wilk	Mean	Skew-ness	Kur-tosis	Ind. Samples t-test	Chi-square	Mann-Whitney U
Avg. # of Teeth with EH Defects	.859 (p = .001)	.4563	-0.267	-1.070	-	-	94.500 (p = .186)
Avg. Total # of EH Defects	.870 (p = .001)	.9750	.369	-1.527	-	-	91.000 (p = .161)
Avg. Severity of EH Defects	.950 (p = .146)	1.1344	.123	-0.997	1.789 (p = .084)	12.600 (p = .399)	-

TABLE 16: Total Dentition (Permanent and Deciduous) by Tooth Type

Tooth Type	# teeth observed	% observed
Incisors	190	29.0
Canines	93	14.2
Premolars	144	21.9
Molars	229	34.9
Total	656	100.0

TABLE 17: Prevalence of LEH in Permanent Teeth by Tooth Type

Tooth Type	# teeth observed	% observed	# teeth affected	% affected	# defects	Average # defects/ tooth
Incisors	139	26.5	72	51.8	216	1.6
Canines	73	13.9	47	64.4	149	2.0
Premolars	144	27.4	83	57.6	149	1.0
Molars	169	32.2	78	46.2	105	0.6
Total	525	100.0	280	53.3	619	1.3

TABLE 18: Prevalence of LEH in Permanent Teeth by Tomb Type

Tomb Type	# teeth observed	% observed	# teeth affected	% affected	# defects	Average # defects/ tooth
Cappuccina (n=26)	310	59.0	167	53.9	411	1.3
Disturbed (n=3)	86	16.4	40	46.5	65	0.8
Libation (n=3)	69	13.1	33	47.8	61	0.9
Mortar (n=3)	57	10.9	40	70.2	82	1.4
Other (n=1)	0	0.0	0	0.0	0	0.0
Soil (n=5)	3	0.6	0	0.0	0	0.0
Total	525	100.0	280	53.3	619	1.2

TABLE 19: LEH Statistical Analysis by Tomb Type

Variable	Shapiro-Wilk	Mean	Skew-ness	Kurtosis	Chi-square	ANOVA	Kruskal-Wallis
Avg. # of Teeth with EH Defects	.855 (p = .000)	.2731	.655	-0.790	-	-	10.276 (p = .068)
Avg. Total # of EH Defects	.715 (p = .000)	.6640	2.607	9.695	-	-	10.759 (p = .056)
Avg. Severity of EH Defects	.860 (p = .000)	.8069	.617	-0.935	-	-	10.354 (p = .066)

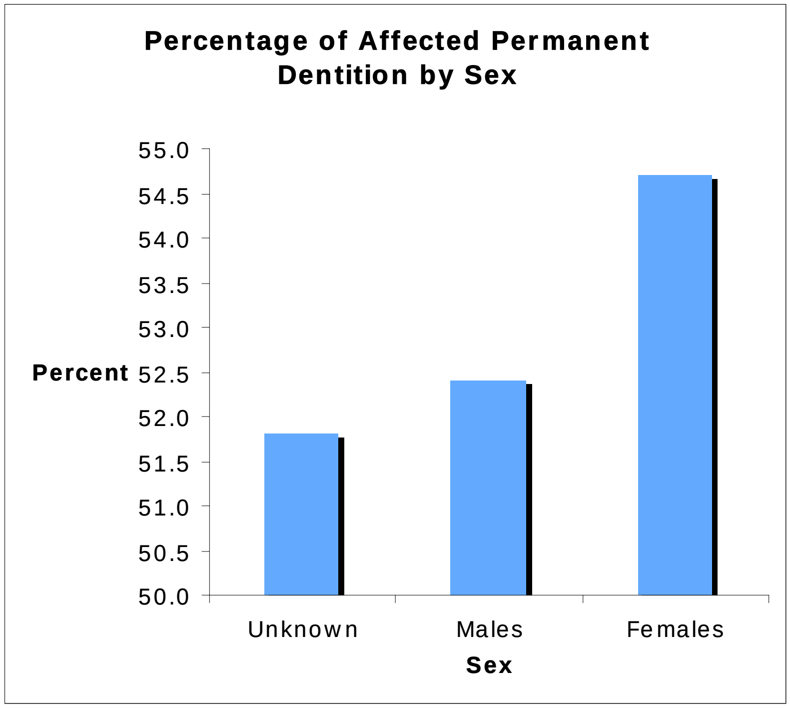

Fig. 22: Percentage of affected permanent dentition by sex.

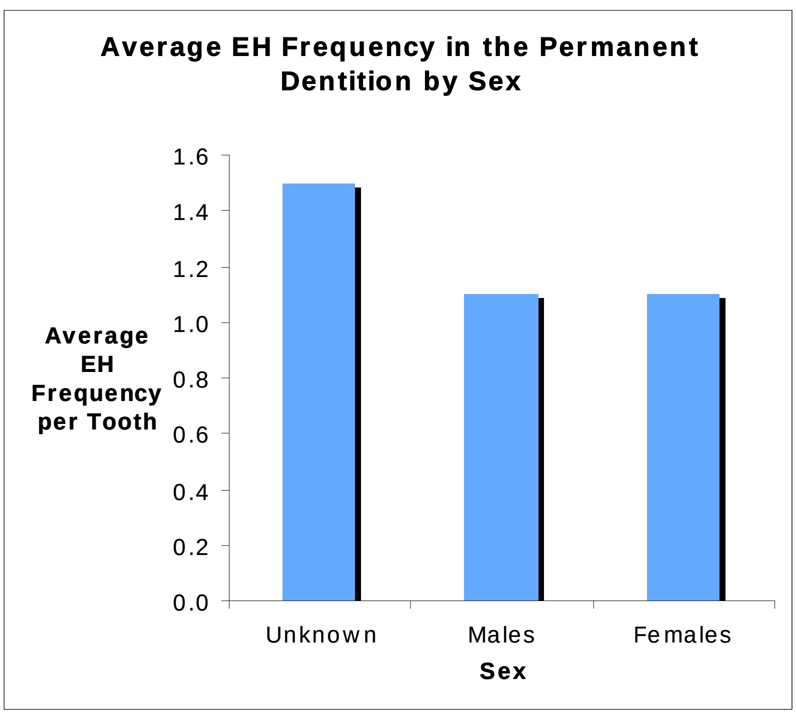

Fig. 23: Average EH frequency in the permanent teeth by sex.

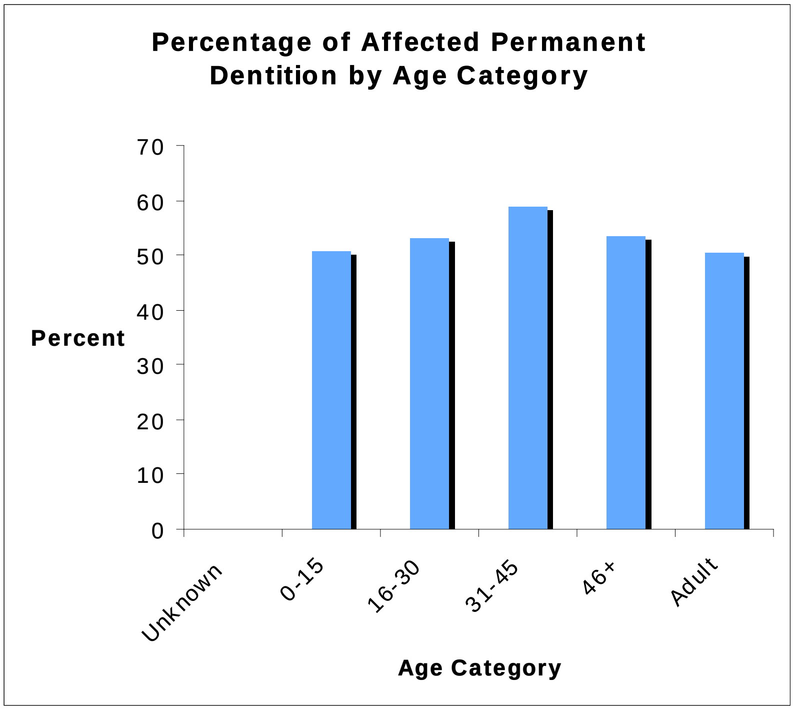

Fig. 24: Percentage of affected permanent dentition by age category.

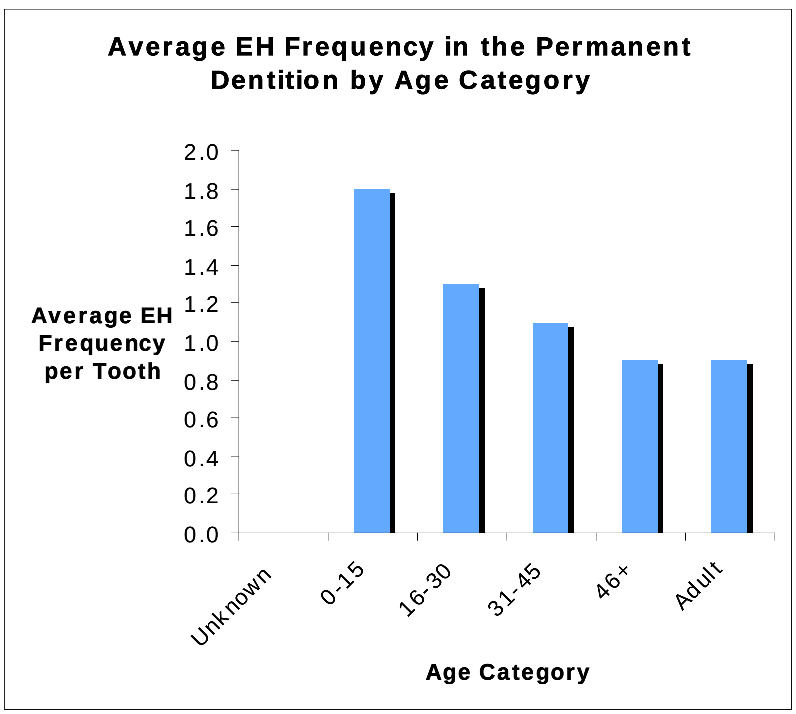

Fig. 25: Average EH frequency in the permanent dentition by age category.

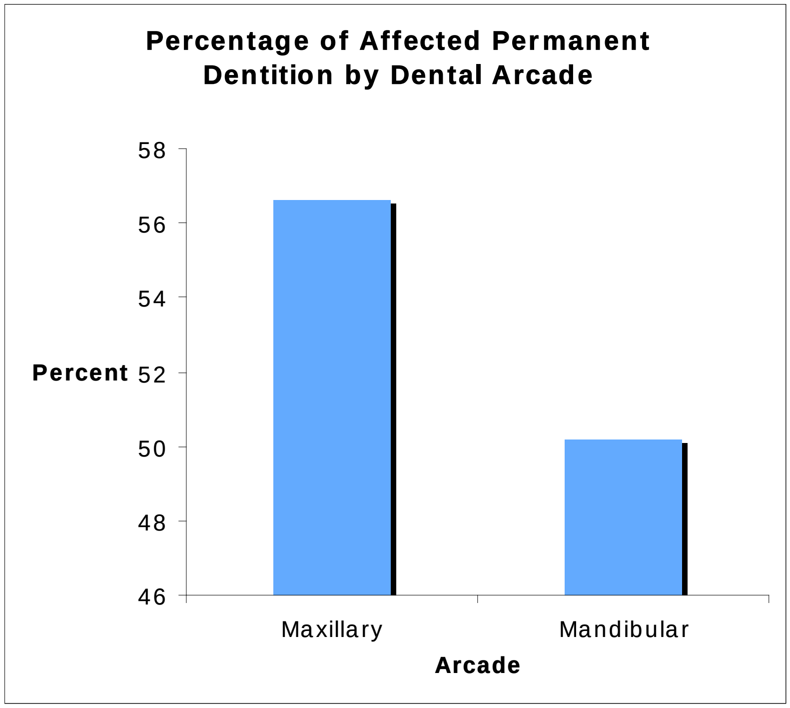

Fig. 26: Percentage of affected permanent dentition by dental arcade.

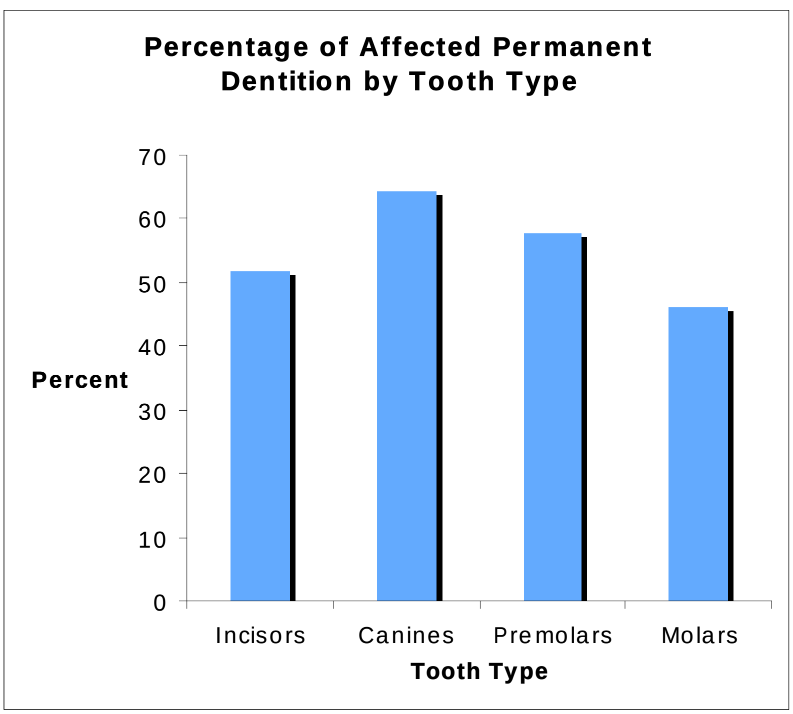

Fig. 27: Percentage of affected permanent dentition by tooth type.

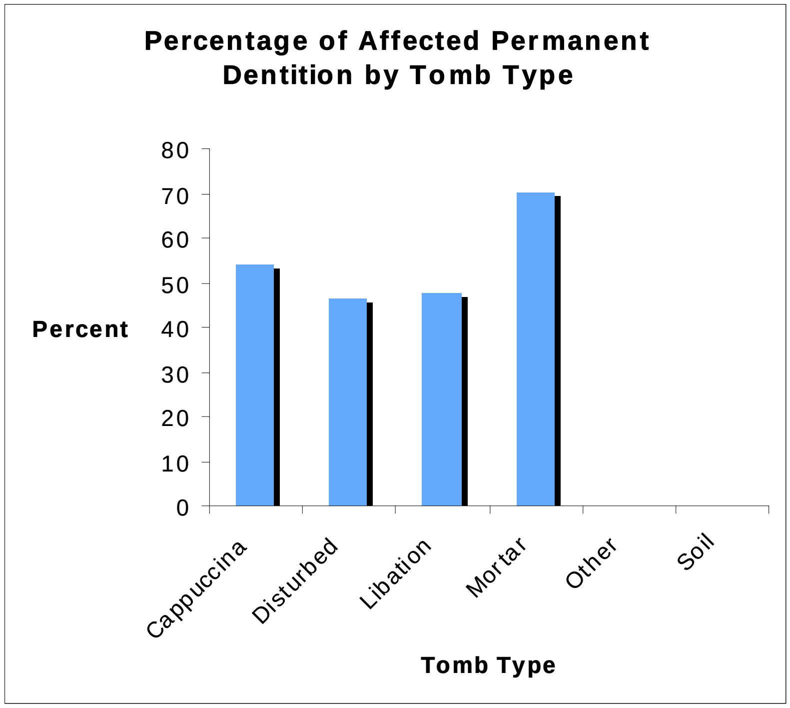

Fig. 28: Percentage of affected permanent dentition by tomb type.

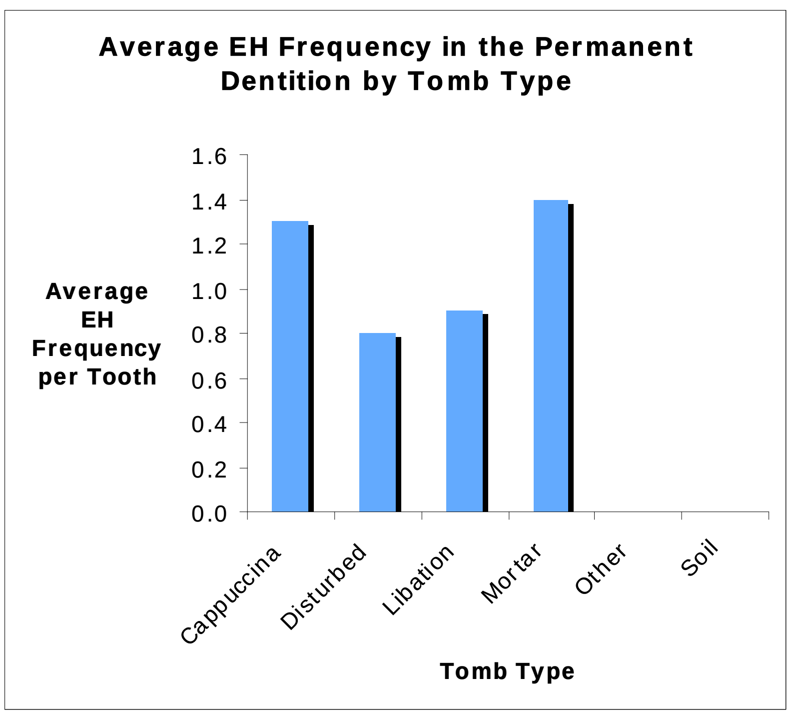

Fig. 29: Average EH frequency in the permanent dentition by tomb type.

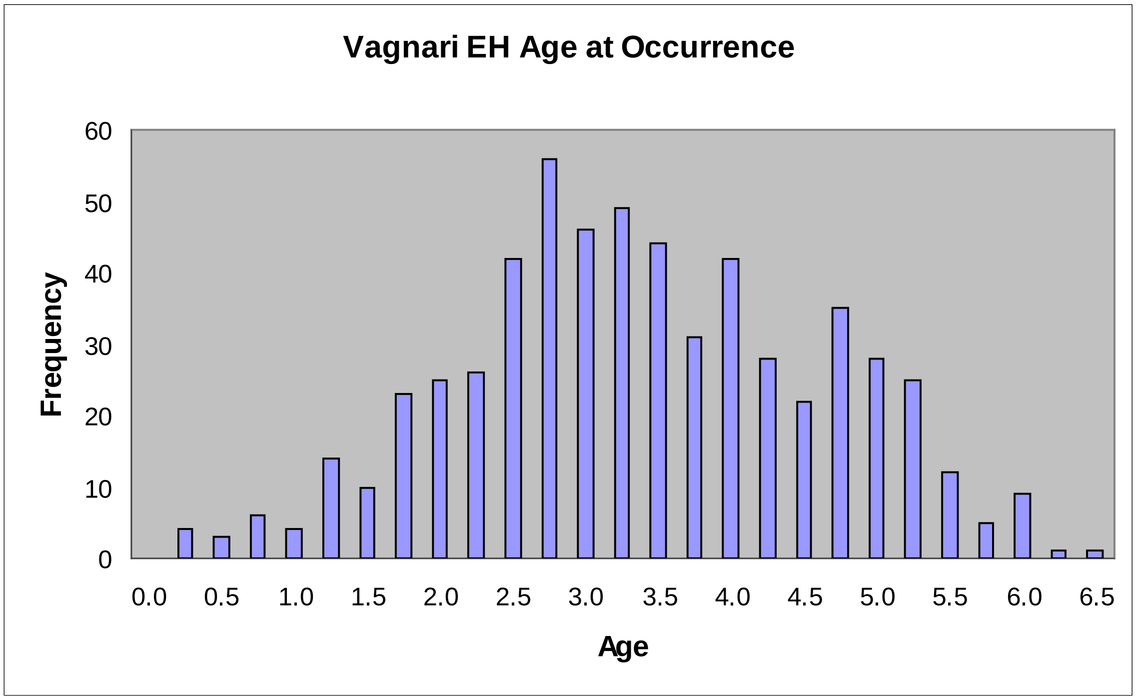

Fig. 30: Enamel hypoplasia age (in years) at occurrence histogram of individual hypoplastic events.

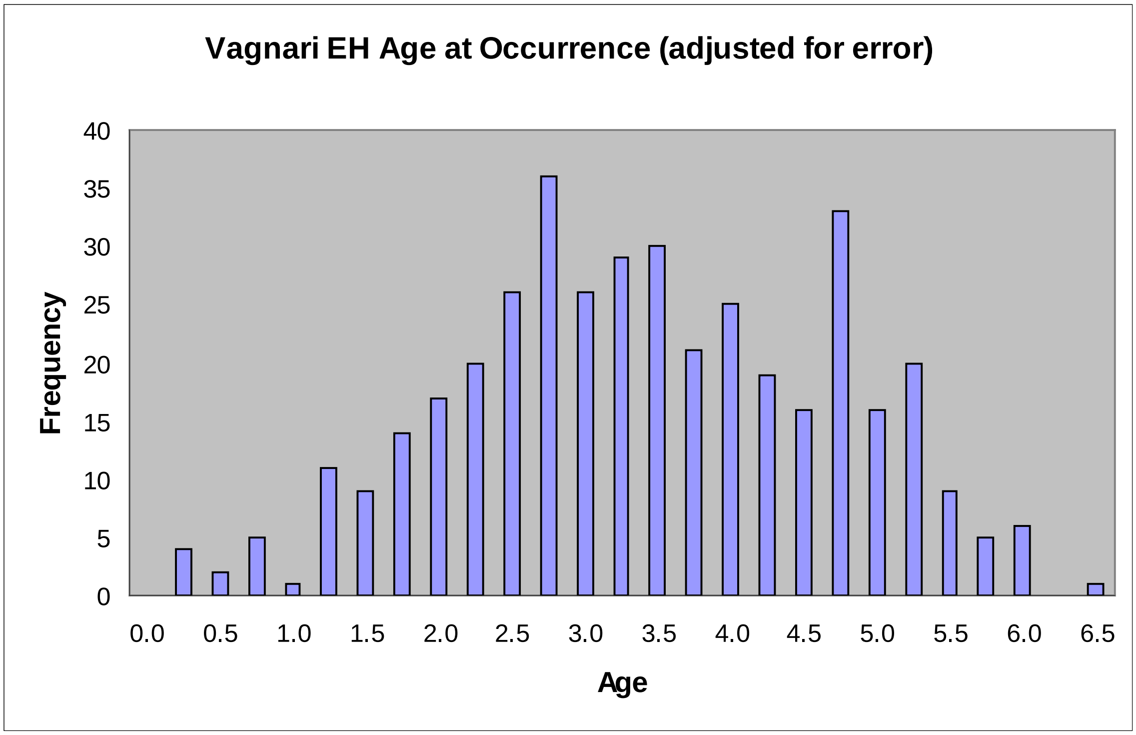

Fig. 31: Enamel hypoplasia age (in years) at occurrence histogram of individual hypoplastic defects that has been adjusted for the possibility of error due to redundancy.

CHAPTER 6

DISCUSSION

Intra-Site Comparison

Examination of 48 individuals in the Vagnari skeletal sample (infants, subadults, and adults) revealed that 31 (64.6%) had at least one permanent tooth with a visible stress event marked by an LEH. None of the deciduous teeth examined showed visible hypoplastic defects.

LEH by Sex

A comparison between the sexes of the "Average Number of Permanent Teeth with Defects" (males - 52.4%; females – 54.7%), "Average Number of Hypoplastic Defects" (males – 1.1; females – 1.1), and "Average Severity Ranking of Defects" (males – 1.0; females – 0.9) were not significantly different (see Table 7).

According to the ancient literature, sexual stratification of ancient Roman society was commonplace with males receiving preferential treatment and more access to resources (e.g., education, nutrition, health care) (e.g., Casson, 1998; Harlow and Laurence, 2002; Ward et al., 2003, among others). According to Galen of Pergamum, males and females were distinctively different beginning at the moment of conception (Harlow and Laurence, 2002). Male and female offspring were thought to be produced by opposite testes from the father and carried on opposite sides in the womb of the mother. The female child was referred to as an imperfect example of the ideal male specimen (Harlow and Laurence, 2002).

Following birth, the inferior view of female infants was perpetuated by Roman cultural traditions. Roman naming practices are an example of gender distinction in Roman culture. Female children were given a feminine version of the father's *nomen*, which all female offspring would share. In contrast, male children were given a full *trianomina*, which would include taking the *nomen* and the *conomen* of the father as well as a distinct *praenomen* that would distinguish each son. The practice of exposure and infanticide in the Graeco-Roman world has been discussed and debated at length, and some have argued that the practice was more common for females (e.g., Golden, 1981, 1988; Harris, 1994; Rawson, 2003). However, both Riddle (1992) and Scott (2000) have concluded that the literary evidence for female infanticide is weak.

A male child, particularly the first born child, was given preference because of his ability to continue the family bloodline (Harlow and Laurence, 2002). In contrast, there may have been biases in childcare for female children (Riddle, 1992). Further, a woman would carry the legal status of a child throughout her lifetime as a result of her perceived physical and mental weakness. A father had all control of and legal rights to his children, while a woman could not wield such power (Harlow and Laurence, 2002). In fact, women were to be guided in the legal realm just like children (Dixon, 1992).

As such, it could be hypothesized that male children were generally given better care and had access to more nutritious foods than female children in ancient Rome, meaning that the prevalence of EH's might be expected to be higher among females. This is not the case with the Vagnari sample. The similarity of defect occurrence and prevalence between males and females seems to suggest that both sexes were equally exposed to similar levels of stress during periods of infancy and childhood.

Other Roman studies have also compared EH prevalence between males and females. Belcastro and co-workers (2004) compared per tooth and per individual frequencies for the sexes in Quadrella and Casalecchio de Reno. The females of Casalecchio de Reno demonstrated significantly higher per tooth frequencies than males (males – 42.0%; females – 58.0%) but males demonstrated higher per individual frequencies than females (males – 100.0%; females – 95.0%) (Belcastro et al., 2004). The individuals of Quadrella demonstrated no significant differences between the sexes for per tooth frequencies (males – 56.0%; females – 62.0%) and per individual frequencies (males – 92.0%; females – 100.0%) (Belcastro et al., 2004). Paine and colleagues (2009) also reported per individual frequencies for males and females in the Urbino sample (males and females – 100.0%). Cucina and associates (2006) reported per tooth frequencies (males – 62.0%; females – 58.5%) and mean number of defects (males – 1.5; female – 1.5) for each sex in the Vallerano sample that were not significantly different. Of these results, only the per tooth frequencies (males – 42.0%; females – 58.0%) from Casalecchio de Reno proved to be significantly different (Belcastro et al., 2004). The EH evidence from these Roman sites (northern and central Italy) suggests that there was no consistent bias against females in these rural and suburban contexts, which is consistent with the evidence from Vagnari. It is possible that children living in rural and suburban Roman contexts were treated equally regardless of sex, contrary to the impression provided by the ancient literary sources.

Though ancient literary sources describe a sexually stratified Roman society beginning at birth, it should be remembered that these literary sources often described the customs and lifestyles of people living in the upper echelons of Roman society. The hypoplastic evidence from Vagnari and other contemporaneous sites suggests that such customs may not have been universal throughout the Roman world. These contradictory findings emphasize the need for multi-faceted approaches (i.e., historical documents, archaeological, biological, etc.) to study culture and life ways of past populations.

LEH by Age Category

A higher average number of defects were observed in the 0-15 year old (subadult) age category (1.8 defects per tooth). In contrast, the 46+ year old age category had the lowest average number of defects (0.9 defect per tooth) (see Table 11). Differences of “Average Number of Permanent Teeth with Defects”, “Average Number of Hypoplastic Defects”, and “Average Severity Ranking of

Defects" were found to be statistically significant between different age groups (at $p \leq 0.05$) when the sample was divided into 15-year intervals, but not when the data were collapsed into two age categories; subadults (0-15 years) and adults (16+ years), suggesting that the significant differences are not simply between the subadults and adults. Goodman and Armelagos (1985) suggested that young mortality indicates an increased amount of significant physiological stressors. The evidence from Vagnari supports this hypothesis, meaning that the subadults who were chronically or repeatedly stressed (as indicated by higher average number of defects) also died at a younger age. These subadults actually had slightly fewer teeth affected by one or more defect (50.8%) (see Table 11), but those teeth that were affected had more per tooth.

It could be possible that adults were prioritized over children in terms of access to resources. Prowse (2007) provides skeletal evidence that indicates that the people buried at Vagnari were engaged in strenuous physical activity. It seems reasonable to suggest that an adult labor population would be of more immediate value to an Imperial overseer while children would be of value in the future. This is not to say that the children at Vagnari were unimportant, but that they may not have had access to the most nutritional foods or the best health care. On the other hand, it may also be possible that the children were also part of the labor force at Vagnari and this work put children at risk of being affected by additional stressors after weaning was completed (e.g., difficult manual labor, unmet increased nutritional needs during growth, contact with disease, etc.).

Individuals in the 31-45 year age category had the highest percentage of teeth affected (59%) and the highest “Average Severity Ranking of Defects” (1.3), but exhibited the lowest average number of defects per tooth (0.9). In contrast, the 0-15 age category had the lowest percentage of teeth affected (50.8%) and a comparatively low “Average Severity Ranking of Defects” (0.3) while exhibiting the highest average number of defects per tooth (1.8). According to Wood and colleagues (1992), dental indicators of stress, such as EH, represent an individual’s ability to cope with stressors since an individual would need to survive in order for the enamel defect to be evident in the tooth crown enamel. These nonspecific stress defects demonstrate individual resilience to environmental pressures (Wood et al., 1992). What is important is that these individuals survived these stress incidents in order to exhibit these defects on the permanent dentition. This evidence from Vagnari seems to suggest that an individual could survive a severe stress episode without a significant impact on mortality. In contrast, the subadults who exhibited more stress episodes that were comparatively less severe died at a considerably younger age. This may suggest that chronic, repeated stressors had a greater impact on mortality when compared to the severity of stress episodes.

LEH by Dental Arcade

Teeth in the maxilla (56.6%) were more frequently affected in comparison to the mandible (50.2%). There was also a higher average number of defects on the maxilla (1.4 defects per tooth), which suggests that maxillary teeth are more susceptible to hypoplastic defects, although these results are not statistically significant (see Table 14).

Goodman and Armelagos (1985) suggest that maxillary central incisors and mandibular canines are the most susceptible teeth in the permanent dentition. The maxillary central incisor tends to be the most susceptible to early forming hypoplasias as a result of its early tooth crown formation beginning at around 3 months and completing formation at approximately 4 to 5 years (Goodman and Armelagos, 1985; Hillson, 1996). The mandibular canine has a longer tooth crown formation period that also begins at around 4 months but completes formation at approximately 6 to 7 years (Hillson, 1996).

In addition, there is no systematic difference in the crown formation times between the maxillary and mandibular dentition (Hillson, 1996). As a result, there does not seem to be a physiological reason for the maxillary dentition to be more affected than the mandibular dentition in the Vagnari sample.

LEH by Tooth Type

Canines were more frequently affected by LEH's (64.4%) and showed a slightly higher average number of defects per tooth type (2.0 defects per tooth) than the other tooth classes (i.e., incisor, premolar, and molar) (see Table 17). Canines have a slower rate of enamel deposition and, as a result, take a longer period of time to develop than other tooth classes (Hiller and Craig, 1992; Hillson, 1996). In addition, Goodman and Rose (1985, 1990) concluded that the anterior dentition (i.e., incisor and canine classes) are more often affected in comparison to the posterior dentition (i.e., premolar and molar classes), with the maxillary central incisors and mandibular canines most often affected. Marks and Rose (1985) reported that canines demonstrated a higher prevalence of hypoplastic defects than premolars in their scanning electron microscope study of WB's and EH's. Therefore, this evidence seems to suggest that the findings within the Vagnari sample are consistent with previous research.

LEH by Tomb Type

There is no significant difference in the prevalence or severity of hypoplastic defects between the different burial types (i.e., *a cappuccina*, disturbed, libation, mortar, other, and soil), which suggests that the individuals from the Vagnari cemetery experienced similar levels of stress during infancy and childhood. Each type of burial method was used consistently throughout the cemetery usage period (1^{st} to 4^{th} centuries A.D.), so there is no chronological distinction between different burial types. The results from this EH study indicate that as children, there were also no differences among these individuals in terms of nonspecific indicators of stress. It is also possible that the different burial types do not reflect social status during life, but are preferences of the living based on style or ritual.

In order to illustrate variation in Roman burial treatment, one can look to studies of Roman burials that have described burials that could be associated with high social status. One example is from Bedini and colleagues (1995), who describe wealthy burials at the contemporaneous *necropolis* of Vallerano (2^{nd} to

3rd centuries A.D.) as those burials that contained a marble *sarcophagus* with grave goods containing riches such as gold and jewels. No obviously high status burials have been discovered at Vagnari to date. While Cucina and co-workers (2006) did explore EH at the site of Vallerano, these 5 wealthy burials were not enough to conduct an investigation of variability with respect to social stratification.

Age-Specific Occurrences

The age distribution of individual hypoplastic events demonstrated peaks of hypoplasia occurrence occurring around 1.25, 1.75, 2.5, 2.75, 3.25, 4.0, and 4.75 years of age (see Figure 30). The adjusted age distribution demonstrated peaks of hypoplasias occurrence occurring around 0.25, 0.75, 1.25, 2.75, 3.5, 4.0, 4.75, 5.25, and 6.0 years of age (see Figure 31). The highest frequency occurs at around 2.75 years of age, followed by a gradual decline with the latest observable defect occurring at around 6.5 years of age. This general increase with a peak at around 2.75 years, and then a gradual decline suggest that infants were experiencing higher levels of stress during this period. One possible explanation for this pattern is the physiological stress experienced during the process of weaning and the introduction of new foods to the infant.

During the weaning process, disease and mortality may result when an infant is no longer receiving the benefits (i.e., passive immunity, nutrition) from the breast milk of the mother (Katzenberg et al., 1996). In addition, infants and children can become susceptible to malnutrition and undernutrtion with the introduction of new food sources that are nutritionally incomplete or not prepared properly (Katzenberg et al., 1996; Moggi-Cecchi et al., 1994; Rodney, 1983). Children are also exposed to new pathogens in the environment, either through food-borne bacteria or from other sources.

Much of what researchers know of nursing and weaning in Rome come from wet nurse contracts and ancient writers such as Soranus (Green, 1951; Masciadri and Montevecchi, 1984; Tempkin, 1956). Rome had a long history of prescribing the services of wet nurses and avoiding colostrum, which could deprive infants and young children of much needed nutrition and antibodies (Garnsey, 1999; Harlow and Laurence, 2002; Stini, 1985). Direct evidence of such nursing practices are difficult to discover. Ancient literature and wet nursing contracts suggest that the weaning process in Rome began around 6 months of age and neared completion at around 2 to 3 years of age, although there is likely to have been variation in this pattern throughout the Roman Empire (Fildes, 1986). Furthermore, this evidence indicates how nursing and weaning should be rather than how these activities were actually conducted. Another factor to be mindful of is that the services of wet nurses were available for the families that could afford them (Casson, 1998; Harlow and Laurence, 2002). As such, it is unlikely that the laborer population at Vagnari would have been able to afford such luxuries.

There are several lines of evidence deriving from the skeletal remains that can help researchers approximate the onset, duration, and completion of the weaning process. Preliminary isotopic evidence ($\delta^{15}N$) indicates a weaning age of about 2.5 years at the site of Vagnari, which is consistent with the EH data that suggest a period of peak stress occurring around 2.75 years (Prowse, personal communication).

This hypothesis corresponds with a hypoplastic defect study at Roman period Mendes (Egypt) (332 B.C. to 395 A.D.), in which Lovell and Whyte (1999) found that hypoplastic stress indicators occurred more frequently between 3-5 years of age, with evidence of physiological stressors beginning in utero and until as late as 6 years of age. This evidence suggests that mothers experienced malnutrition during pregnancy, children experienced a high amount of stress (specifically malnutrition, illness, and fevers) throughout childhood, and weaning and its associated physiological difficulties may have occurred relatively late in childhood (between 3-5 years of age) (Lovell and Whyte, 1999). Furthermore, Lovell and Whyte (1999) demonstrated that the majority of EH's were exhibited by permanent dentition in this skeletal sample, which is also similar to what was observed at Vagnari. None of the deciduous teeth in the Vagnari sample showed any visible hypoplastic defects, which may indicate a comparatively less stressful intrauterine environment or greater maternal buffers for the individuals in this sample.

Cucina and co-workers (2006) found that EH's began at around 1-1.5 years with peaks occurring around 3.0-3.4 years of age and 4.5-4.9 years of age at the Roman necropolis of Vallerano (2^{nd} to 3^{rd} centuries A.D.) located near the city of Rome. These peaks were attributed to contact with diseases (such as malaria) as a result of having already been weaned and thus lacked passive immunity from the breast milk of the mother, suggesting that the weaning process had neared completion at around 3 years of age (Cucina et al., 2006).

This hypothesis also concurs with data from an isotopic ($\delta^{15}N$ and $\delta^{13}C$) study of Roman period Kellis (Dakhleh Oasis, Egypt) (1st to 5th centuries A.D.), in which Dupras and Tocheri (2007) reported results indicating weaning completion occurring by 3 years of age. In addition, isotopic ($\delta^{15}N$) evidence from the Isola Sacra necropolis located near Rome (1st to 3rd centuries A.D.), demonstrated initiation of weaning at around 2.5 years of age and completion by 5 years of age (Prowse et al., 2008). Furthermore, after 2 years of age, the isotopic data demonstrate an absence of breast milk ($\delta^{15}N$) as the primary food source and the introduction of C_3 plants (i.e., wheat, barley, rice, etc.) and animal food sources ($\delta^{13}C$) (Prowse et al., 2008). This evidence is consistent with evidence from ancient literary sources, which recommended weaning foods of moistened breads, soft cereals, and eggs (Garnsey, 1999). All of these studies are generally consistent in their findings concerning the onset and completion of weaning, typically not occurring before about 2 years of age and with a fairly extended period during which infants and children would be gradually introduced to new foods. According to Massler and colleagues (1941), another variable that may contribute to the higher number of defects around this age is related to periods of increased metabolic susceptibility in relation to increased physiological demands associated with rapid growth (see Chapter 2).

Several difficulties are associated with determining age chronologies of EH's and isotopic studies of weaning. Enamel hypoplasias are more readily observed near the tooth crown cervix rather than the occlusal edge, which is the portion of the tooth crown that represents the earlier periods of tooth crown development (Hillson, 2005; King et al., 2002). These earlier periods of enamel deposition may also be unavailable due to attrition. These difficulties could lead to an underestimation of EH timing. It should also be noted that many have suggested that age chronologies derived from nonspecific stress markers can be incorrect by up to 1 year (e.g., Hillson, 1992b; Lovell and Whyte, 1999; Ritzman et al., 2008), while evidence of the timing of weaning determined from isotopic evidence can be delayed by about 6 months due to time required for bone to incorporate the isotopic signal of the dietary transition (Prowse et al., 2008).

LEH by Individual - Comparison with Other Sites

Sites with archaeological and historical contexts similar to the site of Vagnari have reported moderate to high individual EH frequencies (see Table 20).

Individual frequencies of EH's higher than those at Vagnari were reported in a sample from Quadrella (95-95.2%), an extra-urban population located in central Italy, near the modern city of Molise (Belcastro et al., 2004). Belcastro and co-workers (2004) also inferred high levels of non-specific childhood stress and malnutrition for the site of Quadrella. Of the eight comparison sites, Quadrella is geographically the closest to Vagnari (about 247 kilometers away).

In another skeletal sample from Casalecchio di Reno, a *necropolis* associated with a small town of poor farmers and traders located in the north near the modern city of Bologna (2nd to 5th centuries A.D.), Belcastro and co-workers (2007) reported an individual EH frequency of 93%, Belcastro and colleagues (2004, 2007) inferred that these individuals were exposed to high levels of stress and poor nutrition during childhood.

Similar to the site of Quadrella, the site of Vallerano was centrally located in the Italian peninsula. A sample of 77 individuals exhibited high levels of EH frequency (92.9%) (Cucina et al., 2006). However, Cucina and colleagues (2006) reported that many individuals from this sample exhibited multiple stress episodes with few living beyond 50 years of age. Evidence suggests that the Vallerano individuals were poor laborers or slaves and the authors suggested that the interplay between malnutrition and disease susceptibility likely affected this population (Cucina et al., 2006).

Other sites with similar rural contexts (i.e., Lucus Feroniae and Ravenna) also reported higher frequencies (82% and 84%, respectively) of individual EH's (Facchini et al., 2004; Manzi et al., 1999). The results from the Vagnari sample (64.6%) are considerably lower than the high individual frequencies of EH's reported from the rural sites of Casalecchio di Reno, Quadrella, and Vallerano. In contrast, the results from the Vagnari sample are slightly higher than the individual frequencies of EH's from the urban site of Rimini (57.1%). Facchini and associates (2004) found significant correlations between cribra crania, cribra orbitalia, and EH's in both the Ravenna and Rimini samples, which they attributed to parasitic infections and nutritional deficiencies during childhood. Finally, the results from the Vagnari sample are considerably higher than the individual frequencies of EH's from the urban site of Mendes (44%), which is located outside of the Italian peninsula (Lovell and Whyte, 1999). However, Lovell and Whyte (1999) utilized the deciduous and anterior permanent dentition to calculate this individual EH frequency. When the same limits are applied to the Vagnari sample, the individual EH frequency lowers from 64.6% to 56.1%, which is still higher than the frequency reported for Mendes (44%) (Lovell and Whyte, 1999) (see Table 20). Lovell and Whyte (1999) attributed the low EH frequencies to relatively well-nourished and healthy children at Mendes.

Several possibilities exist for these reported differences. First, the data collection methods utilized in this study may have been more stringent than the earlier studies, including the exclusion of questionable enamel disruptions and teeth that exhibited high amounts of attrition, calculus, or carious lesions. The methodology utilized for this study produces a more accurate assessment of EH prevalence. For this study EH presence is recorded if the defect is palpable on both antimeres at similar levels, observed on another tooth that was developing during the same time period, or circumscribes the tooth (after Corruccini et al., 2005). This methodology helps to ensure a systemic origin of the defect and helps to reduce the possibility of overestimation. It is possible that some of the comparison studies may have overestimated the prevalence of EH's in their samples.

For example, Cucina and co-workers (2006) examined remains from Vallerano (2nd to 3rd centuries A.D.). This study recorded the presence/absence, scored defects (slight/severe), and measured defect position of only LEH (Cucina et al., 2006). Cucina and colleagues (2006) did not indicate how LEH's were defined for this study nor did they indicate how scoring (slight/severe) was determined. Defect position on the tooth was only recorded for the anterior dentition (i.e., incisors and canines), though the researchers did measure the onset and cessation of each linear defect (Cucina et al., 2006).

Another example is a study by Paine and co-workers (2009) that examined rural middle class remains from two coeval *necropoli* at Urbino (1st to 3rd centuries A.D.), located in central Italy. The presence of EH's was recorded for all teeth (after Cucina et al., 2006; Goodman and Armelagos, 1985; and Hillson, 2001). An individual LEH prevalence of 100% was reported for the Urbino sample (Paine et al., 2009). This prevalence is higher than any other Imperial Roman EH study, suggesting that there may have been an overestimation of EH presence. The researchers were not specific about their methodology, so it is not possible to define what methods may have contributed to a prevalence overestimation, if in fact there was an overestimation (Paine et al., 2009). What can be certain, is that Paine and associates (2009) cited the standards utilized by Cucina and colleagues (2006) (see page 30). Only individuals with teeth were included in the final analysis, contributing to a small sample size of 35 individuals. This small sample size could contribute to statistical errors, which the authors recognized (Paine et al., 2009).

Another possible explanation for the variability in individual LEH frequency between these different sites is that the Vagnari population was actually experiencing fewer disruptions during amelogenesis as a result of lower amounts of systemic stressors experienced during childhood than other comparable skeletal samples from both urban and rural contexts. It is possible that the comparatively higher prevalence among most of the urban samples (i.e., >90%) (with the exception of Rimini) is related to increased risks of morbidity in those environments. The more rural sites of Lucus Feroniae and Ravenna have slightly lower levels of EH, suggesting less morbidity in these environments.

It has been suggested that the Vagnari site was part of a rural Imperial estate (Small et al., 2003; Small and Small, 2005). Although research has not been conducted concerning agricultural activities, it seems likely that this rural estate was self-sustaining in terms of animal husbandry and grain production. In comparison to prehistoric hunter-gatherer societies, the spread of disease and food shortages are among some of the risks associated with sedentary lifestyles. Recurrent undernutrition and nutrient deficiencies (e.g., vitamins A and D) can lead to the formation of EH's (Lovell and Whyte, 1999). Sedentary environments provide an opportune environment for infectious disease to thrive. Individuals within a sedentary environment have frequent contact with one another as well as animals (Barrett et al., 1998; Larsen, 1997). However, there is no clear evidence from this skeletal sample of chronic (or acute) infectious disease, so this may suggest low levels of infectious disease at Vagnari or low survival rates of individuals who were infected. Evidence of infectious disease is difficult to ascertain in the archaeological record. Epidemics can sometimes be inferred from evidence such as mass burials (or "plague pits"), which could provide an expedient and efficient burial method during periods of high mortality rates. Furthermore, if an individual were to die of an infectious disease, the disease would be unlikely to affect the skeletal tissues. To date, no evidence for infectious or epidemic disease has been discovered at Vagnari. The relatively low prevalence of EH's, in comparison to other contemporaneous sites in Italy, may indicate that the isolated location and self-sufficiency of this rural estate contributed to a generally healthy environment. This rural estate would have had a lower population density than urban environments, which may have also contributed to a decreased risk of illness.

Although the site of Vagnari was relatively isolated from major urban centers in the Roman period, its location along a prominent communication route (i.e., the *Via Appia*,) may have provided the individuals living at Vagnari with access to resources such as imported foods and goods as discussed by Small and Small (2005). However, Vagnari's close proximity to the *Via Appia* may have also meant an increased risk of the spread of disease through contact. It is probable that many epidemics occurred during the Roman Empire, though few are documented in detail. Researchers rely heavily upon historic documentation of these epidemics.

One such epidemic was the Plague of Antonine, which occurred during the reign of Marcus Aurelius (161 to 180 A.D.), affecting Asia Minor, Egypt, Greece, and Italy (Galen, *On the Natural Faculties*). It is possible that this plague was brought to the Roman Empire by Roman soldiers returning from the Antioch sea port of Seleucia, located in modern day Syria. Less than a century later, the Plague of Cyprian originated from Egypt in 251 A.D. It took a major toll on the Roman army and laboring populations between 250 to 270 A.D.

By the 5th century A.D. disease pools began to form as the result increased migration and trading (Barrett et al., 1998). An example of this "pooling" comes from the final documented plague of the Roman Empire, which was the Plague of Justinian beginning between 541 to 542 A.D. that took place after the abandonment of the Vagnari cemetery in the 4th century A.D. This plague originated either in Ethiopia or in central Asia and was transmitted along well-developed transportation routes by military and traders. By 543 A.D., the plague had reached the Italian peninsula. This plague particularly affected coastal port cities where there was an "exchange of infections as well as of goods" (McNeill, 1977:125).

These types of documents serve to provide a biased view of the past in that ancient writers may not have experienced these epidemics first hand. At times the documents are not thorough enough to clearly distinguish fact from opinion, much less determine the actual disease being discussed. Furthermore, these literary accounts may not be able to be validated by other sources. When epidemics are not recognized in historical data or when the information concerning the epidemic remains inconclusive, "skeletons furnish the best and, in many cases, the only picture of health available over the millennia", which is why a bioarchaeological approach is so paramount in understanding past populations (Steckel, 2003: 213).

However, the data from comparison sites that were contemporaneous with Vagnari do not seem to support this hypothesis. Quadrella, the site with highest frequencies of individual EH, was not located on a major Roman road while Rimini, the site with the lowest reported EH frequencies, was located at the juncture the *Via Aemilia* and the *Via Flaminia*. Nevertheless, it may be possible that other environmental or cultural differences between groups may have been at work. Perhaps the rural, isolated location of Vagnari contributed to an overall higher level of health than has been reported for urban areas of Rome, while its close proximity to roads such as the *Via Appia* provided Vagnari with access to trade and communication with the rest of the Roman Empire. It seems as though Vagnari had all of the benefits of being a part of the Roman Empire without many of the health risks (i.e., communicable diseases) associated with community living.

TABLE 20: Sites with similar temporal, geographical, environmental, and/or socio-economic contexts similar to Vagnari

Site	Date	Location	Locality	Social Class	Teeth Studied	Individual EH Frequency
Vagnari (n=48)	1st – 4th c. A.D.	Gravina in Puglia, Italy (south)	Rural	Low	I^1 & C_L	43.3%
					Anterior	56.1%
					All	64.6%
Casalecchio di Reno[1] (n=62)	2nd – 5th c. A.D.	Bologna, Italy (north)	Rural	Low	All	93.0%
Isola Sacra[2] (n=64)	1st – 3rd c. A.D.	Rome, Italy (central)	Urban	Middle	All	81.0%
Lucus Feroniae[2] (n=50)	1st – 3rd c. A.D.	Rome, Italy (central)	Rural	Low	All	82.0%
Mendes[3] (n=39)	Ca. 332 B.C.–395 A.D.	Mendes, Egypt	Urban	Middle	All (dec.), Anterior (perm.)	44.0%
Quadrella[1] (n=67)	1st – 4th c. A.D.	Molise, Italy (central)	Sub-urban	?	All	95.2%
Ravenna (3 coeval necropoli)[4] (n=25)	1st – 4th c. A.D.	Emilia-Romagna, Italy (north)	Rural	Low	All	84.0%
Rimini[4] (n=28)	2nd – 4th c. A.D.	Emilia-Romagna, Italy (north)	Urban	Low	All	57.1%
Urbino (2 necropoli)[5] (n=35)	1st – 3rd c. A.D.	Urbino, Italy (central)	Rural	Middle	All	100%
Vallerano[6] (n=77)	2nd – 3rd c. A.D.	Rome, Italy (central)	Sub-urban	Low	All	92.9%

1 Belcastro et al. 2004, 2007
2 Manzi et al. 1999
3 Lovell and Whyte 1999
4 Facchini et al. 2004
5 Paine et al. 2009
6 Cucina et al. 2006

CHAPTER 7

CONCLUSIONS

This thesis has examined infant and childhood health in a rural Roman skeletal sample from Vagnari through the analysis of enamel defects on deciduous and permanent dentition. The results of this analysis are interpreted within the historical and archaeological context of the region.

None of the deciduous teeth exhibited hypoplastic dental defects. This suggests that individuals may have been buffered from stress in the womb. Only the permanent dentition, which forms during the perinatal and early childhood periods, displayed evidence of stress.

The intrasite analysis examined variation in the prevalence and severity of EH's with respect to age, sex, and burial type. The results of this analysis indicate that there are significant differences by tooth between EH prevalence and severity between age categories. Subadults (0-15 years) in this sample experienced a higher average number of defects per tooth in addition to dying at a young age. This evidence seems to suggest that Roman children who did not suffer as many stress and/or malnutrition incidents during dental development may have also been more likely to live until an older age (45+ years old), as there is a progressively lower average number of defects with increased age at death. It is noteworthy that EH's can only be observed on those subadults who survived stress events that were long enough in duration or severe enough to leave a hypoplastic defect. However, these experienced stress events eventually compromised the health of these children, because they died as subadults (< 15 years old). Studies have shown that subadults who are chronically stressed (i.e., disease, malnutrition, illness) are more likely to experience greater levels of morbidity and mortality (e.g., Goodman and Armelagos, 1989, among others). One way to evaluate whether or not the subadults at the site of Vagnari were experiencing greater levels of morbidity would be to explore other indicators of health, such as Harris Lines, fluctuating dental asymmetry, cribra orbitalia, porotic hyperostosis, and periostitis.

Subadults (0-15 years) had the lowest percentage of teeth affected and a lower "Average Severity Ranking of Defects" while exhibiting the highest average number of defects per tooth, but experienced an early death. In contrast, the 31-45 year age category had the highest percentage of teeth affected and the highest "Average Severity Ranking of Defects", while exhibiting the lowest average number of defects per tooth. It seems that hypoplastic defects are capable of demonstrating individual resilience to environmental pressures (Wood et al., 1992). This evidence from Vagnari seems to suggest that an individual can survive a severe stress episode without a significant impact on mortality while chronic, repeated stressors may have a greater impact on mortality.

In addition, this study indicates that there are no significant differences between the sexes in all three variables examined. This finding is contradictory to the Roman sexual stratification described in written records, which suggested that males were treated preferentially from birth, and indicates that male and female children at Vagnari experienced similar levels of stress. This may be due to comparatively equal treatment of male and female children on rural Imperial estates, or it is possible that the preferential treatment of males referred to in the ancient literature is describing only one segment of Roman society, the literate, urban elite. These results are consistent with findings from other contemporaneous skeletal samples from Italy. This study also indicates that there are no significant differences between different burial types for all three variables examined.

Finally, this study demonstrates that EH frequency peaked at around 2.75 years of age and did not decline until after 4.75 years of age. The most likely and conventional interpretation of hypoplastic data is that this peak indicates the process of weaning in this sample. Written records from the Graeco-Roman period and indicates that weaning started after 6 months of age and neared completion at around 2.5-3.0 years of age (Green, 1951; Tempkin, 1956). Comparison of the Vagnari data to other sites in the Roman Empire indicates similar weaning patterns. The decline beginning after 4.75 years occurs after the completion of the weaning process, even if it was as late as 3 years of age. This evidence seems to suggest that childhood stress continued to be present throughout the developmental periods of Roman children. It is possible that these rural Roman children also experienced different types of stressors such as periods of malnutrition and/or morbidity related to infectious disease, as well as periods of increased metabolic demands due to growth.

The purpose of this study was to evaluate general levels of health and stress experienced by Vagnari individuals during infancy and childhood. The previously mentioned results were then compared to data from sites with similar archaeological and historical contexts to the site of Vagnari. The sample from Vagnari has some of the lowest individual EH frequencies; only samples from Rimini and Mendes had lower EH frequencies. The site of Rimini is located in northern Italy and is composed of lower class individuals from an urban environment (Facchini et al., 2004). Cribra crania, cribra orbitalia, and EH's were significantly correlated and attributed to childhood parasitic infections (i.e., malaria, gastrointestinal infections) and nutritional deficiencies (Facchini et al., 2004). The site of Mendes is located outside of the Italian peninsula in Egypt and is composed of middle-class urban dwellers (Lovell and Whyte, 1999). Lovell and Whyte (1999) attributed the low Graeco-Roman EH frequencies to relatively good childhood health and nutrition at the site of Mendes.

Perhaps the comparatively low LEH prevalence observed at Vagnari is also the result of relatively good childhood health and nutrition in comparison to other contemporary populations (i.e., Casalecchio di Reno, Isola Sacra, Lucus Feroniae, Quadrella, Ravenna, Urbino, and Vallerano). The rural location of Vagnari may have reduced the population's exposure to various infectious diseases (i.e., the Antonine and Cyprian plagues) that are known to have existed during the 1st to 4th centuries A.D. Even though this rural location may have provided some protection against "crowd diseases", the site of Vagnari was located along several important communication routes, such as the *Via Appia*.

The close proximity to such important roads would have allowed Vagnari to import necessary goods, some of which may have been foods not readily available in the immediate surroundings of Vagnari. This ability to trade and/or purchase items may have aided the people of Vagnari in periods of difficulty (i.e., drought, crop failure, famine, etc.), thus helping to mitigate malnutrition.

A primary goal of this thesis was to frame this biological evidence within a broader cultural, political, economic, and environmental context. This bioarchaeological approach incorporates a historical, cultural, and environmental framework for this research and provides important information about the lives of children and the physical well-being of a rural working class population in the ancient Roman Empire. It is hoped that this research will contribute to a broader bioarchaeological reconstruction of the lives of this relatively unknown segment of ancient Roman society that is not well represented in the written records.

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APPENDICES

APPENDIX A

LEH Data

ID	Sex	Age	Tomb Type	# of deciduous teeth observed	# of permanent teeth observed	# of teeth affected by LEH	Total # of LEH's observed	Severity ranking
F35	M	Adult	Lib	0	25	16	27	2.0
F36	U	.75-1	Capp	3	0	0	0	0
F37	F	45-49	Capp	0	21	10	17	1.5
F38	U	.75-1	Soil	1	0	0	0	0
F39	U	1-3	Capp	4	0	0	0	0
F40	F	15-17	Capp	0	29	11	30	1.0
F41	U	2	Lib	8	2	0	0	0
F42	M	19-35	Capp	0	17	9	36	1.8
F42A	M	40	Dist	0	21	14	28	1.9
F43	U	3	Capp	14	10	0	0	0
F44	U	2	Lib	15	7	0	0	0
F48	U	1.5-2	Capp	2	0	0	0	0
F49	U	8	Capp	5	12	7	61	1.9
F55	U	5-6	Capp	13	20	1	8	1.1
F59	U	5	Lib	11	23	3	6	1.1
F68	M	45-49	Capp	0	28	13	21	1.1
F86	U	Adult	Capp	0	7	5	10	2.6
F89	F	Adult	Capp	0	3	0	0	0
F92	M	40+	Capp	0	28	3	5	1.7
F93	F	Adult	Capp	0	21	3	4	0.3
F94	F	45-49	Mort	0	22	7	11	0.9
F95	F	Adult	Mort	0	12	4	12	0.9
F96A	M	Adult	Dist	0	23	14	23	1.3
F98	F	Adult	Dist	0	1	0	0	0
F100	U	Adult	Capp	0	8	3	7	1.8
F106	U	1-2	Soil	2	1	0	0	0
F117	F	15-25	Capp	0	26	3	5	0.2
F123	U	1.5	Capp	19	4	0	0	0
F126	M	18-25	Capp	0	8	3	15	0.6
F127	F	16-20	Dist	0	14	6	8	0.5
F130	F	15-19	Dist	0	15	5	5	0.6
F131	M	35-45	Lib	0	30	12	26	1.1
F132	F	Adult	Dist	0	24	1	1	0.1
F137A	F	21-25	Mort	0	30	29	59	2.5

F137B	U	Adult	Lib	0	9	2	2	0.4
F200	F	35+	Capp	0	28	17	23	1.3
F202	U	.75	Capp	12	1	0	0	0
F204	F	Adult	Capp	0	30	18	36	2.2
F205	F	20	Capp	0	24	21	62	2.4
F206	U	Adult	Capp	0	22	14	30	1.8
F210	U	9	Capp	8	22	16	31	1.3
F211	M	Adult	Capp	0	29	2	2	0.1
F212	U	Adult	Capp	0	25	4	8	0.3
F221	U	.75	Soil	7	0	0	0	0
F224	U	.5	Other	3	0	0	0	0
F225	U	Sub-adult	Capp	13	0	0	0	0.4
F227	U	0-.5	Soil	9	0	0	0	0
F229	M	Adult	Soil	0	2	0	0	0

APPENDIX B

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Page 124, Figure 1. The location of Vagnari.

Please advise me if I should contact another email address or if you should require additional information.

Thank you,

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Chrystal L. Nause
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Hi Chrystal

I am enclosing an up-to-date plan of all the Vagnari trenches which you are welcome to use with acknowlegement to Carola Small and Franco Taccogna. If you prefer to use the more out-of-date version which has contours, that is fine by me. Yes, the second figure is current to the end of 2008. The 2009 skeletons have not yet been inserted in the plan.

People have been fascinated by your enamel hypoplasia histogram.

All best wishes

Alastair

From: Chrystal Nause [mailto:clnause@hotmail.com]
Sent: 08 February 2010 20:26
To: Alastair Small
Subject:

Good afternoon, Alastair.

I am preparing the information for your talk on Wednesday. I will have the hypoplasia information and numbers to you by tomorrow morning.

Also, I'd like to use some of your figures in my review of Vagnari site history. I'm not sure who I need to get in touch with in order to obtain reprint permission for these images. I've attached them so you know what I'm talking about. The first is an overview of the Vagnari site (cemetery and architecture) that was published by the BSR. The second is a detailed drawing of the cemetery excavations (published?). Am I right to assume that the second figure is current through the 2008 excavations?

Thanks so much!

-c

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VITA

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The Chancellor's List, Southern Illinois University Carbondale

MWSPE Student Photography Competition, Honorable Mention

2006 Graduate Tuition Scholarship, Southern Illinois University Carbondale
The Chancellor's List, Southern Illinois University Carbondale
Photogenesis Second Annual Photography Competition, Popular Choice Second Place
SPESC Regional Student Show, First Place

2007 Graduate Tuition Scholarship, Southern Illinois University Carbondale
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Major Professor: Tracy L. Prowse

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2002 *Public Health Reports*. March 2002: cover.

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Grassroots: undergraduate magazine for literature and the visual arts. Richards K, McKenzie A, Huber A, editors. Department of English, Southern Illinois University Carbondale. pp. 27, 65, 93.
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